NEW MOTOR VEHICLE EMISSION STANDARDS AND FUEL ECONOMY

HEARINGS

BEFORE THE

SUBCOMMITTEE ON PUBLIC HEALTH AND ENVIRONMENT

OF THE

COMMITTEE ON INTERSTATE AND FOREIGN COMMERCE HOUSE OF REPRESENTATIVES

NINETY-THIRD CONGRESS

FIRST SESSION

ON

OVERSIGHT ON THE RELATIONSHIP BETWEEN NEW MOTOR VEHICLE EMISSION STANDARDS AND FUEL ECONOMY

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NEW MOTOR VEHICLE EMISSION STANDARDS AND FUEL ECONOMY

MONDAY, DECEMBER 3, 1973

House of Representatives,
Subcommittee on Public Health and Environment,
Committee on Interstate and Foreign Commerce,
Washington, D.C.

The subcommittee met at 2 p.m., pursuant to notice, in room 2322, Rayburn House Office Building, Hon. Paul G. Rogers, chairman, presiding.

Mr. Rogers. The subcommittee will come to order, please.

This afternoon and for the next 2 days this subcommittee will hear testimony from both administration witnesses and public witnesses on the several proposals to amend title II of the Clean Air Act emission standards for moving sources.

The Senate Public Works Committee has developed a bill which would freeze the bill for hydrocarbons and carbon monoxide at the 1975 model year levels already established by EPA through model year 1976. A White House proposal would freeze the standards for all three pollutants at the 1975 Federal interim levels through model year 1977 and legislation introduced by one member of this subcommittee would freeze the emission standards at the 1974 level through model year 1977.

Before this subcommittee would move to amend the Clean Air Act's auto emission standards, we would want to carefully and cautiously consider the ramifications of doing so. First we must carefully weigh the cost to our environment of delaying implementations of the standards against the cost to our economy of moving ahead on schedule. We must determine if fuel economy is adversely affected by emission control devices or deleting fuel.

There is understandable concern over the fact that the standards for clean air have caused some penalties in fuel consumption. Some of the evidence would make it appear that we may now be over the worst part of those penalties. It seems, for example, that catalysts will result in a fuel bonus to the consumer of between 6 and 13 percent.

Second, we must determine what effect amending the emission standards will have on related environmental controls such as transportation controls. It makes little sense, I think, to amend the emission limitation standards without considering what the effect would be on other controls that affect the public.

And third, if we determine that delaying the implementation of the standards is necessary in face of the energy crisis, we should also consider whether this subcommittee should mandate certain performance standards for the automobile manufacturers so that all of us, consumer and industry, share in the responsibility of alleviating this Nation's energy shortage.

Legislation that several of us on this subcommittee have introduced—in fact, it was introduced last September—H.R. 11018, would give the Administrator of the EPA the authority to mandate certain performance standards for new automobiles in order to achieve fuel economy wherever feasible.

I am hopeful that the testimony we will hear during these 3 days of hearings will provide us and the American people with the information we need to make an informed decision as to whether the Clean Air Act's emission limitations requirements must be amended in order to deal with the energy crisis.

Because of the urgency involved and the number of witnesses we have scheduled, I have asked each witness to limit his prepared statements to 5 minutes and be prepared for an extensive question and answer period by the members of this subcommittee.

Our first witness this afternoon is the Honorable Russell Train, the Administrator of the Environmental Protection Agency.

We welcome you and Mr. Sansom to the committee, and will be pleased to receive your statements.

STATEMENT OF HON. RUSSELL E. TRAIN, ADMINISTRATOR, ENVIRONMENTAL PROTECTION AGENCY; ACCOMPANIED BY ROBERT SANSOM, ASSISTANT ADMINISTRATOR, AIR AND WATER PROGRAMS; AND ERIC STORK, DIRECTOR, MOBILE SOURCES POLLUTION CONTROL PROGRAM

Mr. TRAIN. Thank you, Mr. Chairman.

As you noted, I am accompanied by Mr. Robert Sansom, the assistant administrator for air and water programs, of the Environmental Protection Agency.

Mr. Chairman and members of the committee, I am pleased to have this opportunity to express my views on automobile emission standards promulgated under the provisions of the Clean Air Act.

I fully realize that the current and projected automotive emission standards are of particular interest to this committee, especially in the light of the imminent shortages of gasoline. I believe it is important, therefore, to briefly discuss the fuel characteristics of the automotive emission standards.

EPA's best judgment of the fuel penalty attributable to meeting emission control standards for the 1973 model year is 10 percent on a sales-weighted basis compared with uncontrolled cars. For large cars, the penalty is greater than 10 percent. For small cars, there has actually been a fuel economy benefit. We expect the overall loss in fuel economy to be lower, because of the accelerating trend toward the purchase of smaller cars. As cars get lighter, the percentage loss attributable to emission controls is reduced for a number of reasons. In the 1974 model year, the sales-weighted fuel economy loss due to emission control is likely to be smaller than it was in 1973 because the sales of small cars appear to be growing even more. As we have testified before, vehicle weight is the single most important factor that governs fuel economy.

For the 1975 model year two sets of new emission standards will go into effect, one for California and one for the balance of the Nation. The domestic and most foreign manufacturers will meet the California standards by, among other things, the use of a catalytic converter. It is our understanding that General Motors and Ford also will use this device for the larger portion of their vehicles sold nationwide.

The catalytic converter is an add-on device that functions in a way that allows two of the major automotive pollutants— unburned hydrocarbons and carbon monoxide—to continue to oxidize after they leave the engine itself. It achieves this by mixing the exhaust gases with air in an environment that prompts completion of chemical reaction, changing hydrocarbons and carbon monoxide into harmless carbon dioxide and water.

By achieving a high degree of control of carbon monoxide and hydrocarbons, the cataylst allows manufacturers to improve fuel economy over 1973 and 1974 model vehicles. In testimony given before the Senate Public Works Committee on November 5, 1973, General Motors stated its 1975 model vehicle on the average would achieve a 13-percent fuel benefit; the other domestic manufacturers also forecast fuel economy gains in the range of 3 to 5 percent. The higher fuel economy levels are attributable to a number of factors, chiefly to the fact that the automotive engine can be adjusted for higher efficiency while allowing the catalyst to achieve the air pollution reductions previously achieved by engine design modifications.

Gasoline economy associated with achieving the statutory standards will still be better than the 1973 and 1974 model years but will be less than that anticipated for the 1975 model year.

Considering the Nation's anticipated gasoline shortage and considering the fact that different emission control systems have different energy requirements, there is clearly a need to provide detailed analysis of this matter. Because we are now in the process of certifying 1975-model-year vehicles and have more data becoming available on fuel economy characteristics of vehicle emission systems, such an analysis is timely. Because of the very great importance for achievement of air quality objectives and meeting energy needs, I believe we should not move ahead precipitously. No decision on model year 1976 need be made until late next spring since certification would not begin until next fall. I do believe it is essential that EPA, working with other Federal agencies, conduct an exhaustive analysis of the environmental and energy implications of emission requirements for 1976 and later model vehicles. This analysis can be conducted in time for early consideration in the next session of Congress. That would provide ample time for full congressional consideration of the most appropriate course of action before a decision needs to be made for 1976 model year cars. Accordingly, I strongly recommended that no changes be made in the automotive emission standards at this time.

Mr. Chairman, this concludes my prepared remarks. I would be glad to answer any questions you or the other members, of the committee might have.

I might point out that we have a couple of charts that might illustrate, briefly, some of the points I have just made.

Mr. ROGERS. I think it would be helpful to have those presented to the committee if we could at this time.

[Testimony resumes on p. 14.]

[The chart and supporting data referred to follow:]

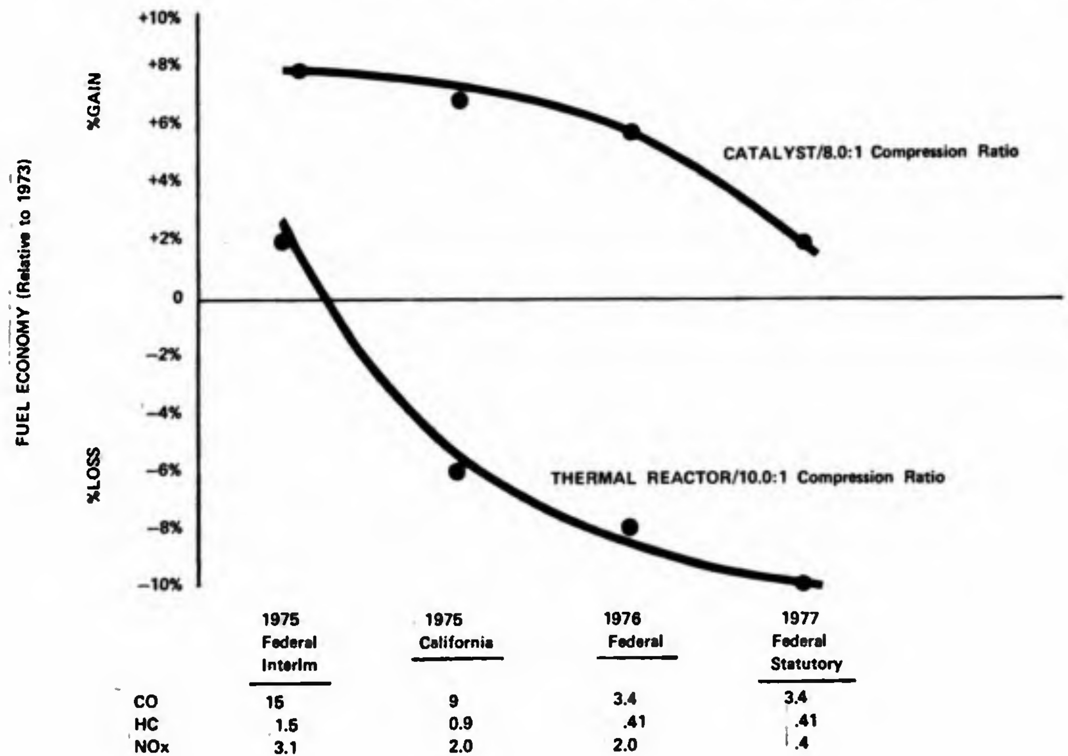
Relationship of Fuel Economy and Emission Standards for Catalysts and Thermal Reactor Emission Control Systems

The data on the attached chart comes from the research and development group of a major oil company. In summary, it concludes:

- Catalyst systems offer improved fuel economy over 1973 vehicles.
  - Catalyst cleans up pollutants in the exhaust, thus allowing calibration of engines for better fuel economy.
  - Numbers in the chart assume the use of commercially available catalyst and good carburetor and EGR systems.
  - If systems are optimized for lowest initial cost instead of fuel economy, gains with catalyst will be reduced.
  - Fuel economy at the statutory HC and CO levels with 2.0 NO_x will be more than 5% better than 1973 (even with 8.0:1 compression ratio and no-lead gasoline).
- Thermal reactor systems offer no improvement in fuel economy over 1973 vehicles at the 1975 interim level, and sharp losses at lower levels of emissions.
  - Thermal reactor relies on extensive heat in exhaust to burn up pollutant. This heat must be generated by burning more fuel.
  - Even use of higher compression ratio (10.0:1) and leaded fuel does not make thermal reactors as good as catalyst from a fuel economy standpoint.

FUEL ECONOMY/EMISSION STANDARDS FOR CATALYTIC AND THERMAL REACTOR EMISSION CONTROL SYSTEMS

(Based on data from research and development efforts of large domestic oil company)
BASELINE-1973 VEHICLE (4,000 lbs) 8.2:1 COMPRESSION RATIO



LEAD: THE FACTS

You have heard a lot lately about the energy implications of removing lead from gasoline. It is time to get the facts straight.

(1) WHAT ACTIONS HAS EPA TAKEN TO REMOVE LEAD?

- One grade of lead-free gas

  In January of this year EPA issued regulations requiring that lead-free gasoline be made available by July 1, 1974. Lead-free gas is required to protect catalytic devices -- a key part of 1975-76 auto emission control systems.

- Lower lead in Leaded Gas

  On November 21, 1973, EPA issued final regulations requiring a 60-65% reduction in the lead content of gasoline by 1979. Today's leaded gasoline constitutes a risk to human health and this regulation is designed to reduce that risk.

(2) WILL THESE ACTIONS COST THE NATION ENERGY?

The net effect of the regulations will be to save energy. Why?

Because the new emission control system which requires lead-free gas will increase fuel economy so substantially that the energy impact of producing lead-free and low-lead gas at the refinery is more than offset by the fuel economy savings.

What are the facts?

If we use the 1973 as the base line and if the statutory emissions standards are imposed in 1976, the energy impact in 1977 and 1980 will be:

	1976 Statutory Standards (1000 barrels per day)	
	1977	1980
Gain in fuel economy	115.0	163.0
Minus loss for lead free	-46	-12.3
Minus loss for low-lead	(-)	-34.4
NET BENEFIT	69.0	116.3

The Benefit varies with the emissions standard. For example:

- If California interim standards for HC and CO were continued to 1977, fuel benefit would be:

	California Interim (1000 barrels per day)	
	1977	1980
NET BENEFIT	150.0	175.0

But in any case, over 69,000 barrels per day net energy savings in 1977 and over 116,000 barrels per day in 1980.

(3) WHAT ABOUT PUBLIC HEALTH?

Environmental lead exposure is a major health problem which effects a small but significant portion of the adult population and up to 25% of children in urban areas. Each year roughly 2-3 thousand children suffer permanent brain damage from lead exposure. Lead from gasoline accounts for approximately 90% of airborne lead and is the only major source of lead which is not presently regulated. EPA beleives strongly that lead from gasoline contributes to excessive blood lead levels, expecially in children, and must be controlled to protect the public health.

(4) WHAT WILL REMOVAL OF 60-65% OF THE LEAD IN GASOLINE MEAN TO THE CONSUMER?

(a) Cost:

The consumer will have to pay for the increased cost of producing and distributing lead-free gasoline. EPA's studies show that this cost will be less than .4 cents per gallon or $13.00 for a car driven 40,000 miles.

The cost impact of the low-lead regulation is even less. The price of gasoline will increase by less than .1 of a cent or $3.00 for a car driven 40,000 miles.

(b) Benefit:

The consumer will benefit from reduced maintenance on cars that do not suffer from lead damage to spark plugs, valves, mufflers, etc. General Motors and Aerospace Corporation have estimated that the annual savings to the average car owner will be around $10.00.

If the average car owner drives 12,000 miles annually, <u>the net savings will be $5.20</u>.

<u>Energy</u>:

- The lead regulations save the nation energy. The savings in 1977, depending on the emissions standard adopted, will be between 69 and 150 thousand barrels per day. In 1980 the savings could be anywhere from 116 to 175 thousand barrels per day.

<u>Health</u>:

- Lead -- is potentially harmful to the public health and any source that can be reduced, such as lead in gasoline should be controlled.

<u>Cost</u>:

- A reduction of lead in gasoline will increase the cost of producing gasoline but the savings from reduced maintenance expenditures will result in an annual saving to the consumer of roughly $5.20.

Estimate of Impact of Easing of Auto Emission Standards on VMT (Vehicle Miles Traveled) Reduction Needs to Meet Ambient Air Quality Standards in 1977 as required by Clean Air Act

Using as an example the Washington D.C. metropolitan area, the following VMT reductions would be needed to meet ambient air quality standards for carbon monoxide and photochemical oxidants by 1977, assuming varying levels of emission controls for 1975 and subsequent model year cars:

Assumption for Emission Standards	Needed VMT Reduction
Current Law -- Federal interim emission standards in 1975, statutory emission standards in 1976 and beyond.	13%
Alternative I -- Federal interim emission standards continued through 1977 model year.	24%
Alternative II -- 1974 emission standards continued through 1977 model year.	32%

The 13% VMT reduction currently contemplated in the Washington, D.C. area Implementation Plan is considered to be stringent, and will be difficult to achieve. Greater levels of VMT reductions could not be achieved without wholesale disruption of the economic and social life of the area. Thus, adoption of either Alternative I or II would for all practical purposes make impossible the achievement of air quality standards in the Washington, D.C. area, with Alternative II obviously making the situation worse.

(NOTE: The estimate for Washington, D.C. can, on a rough basis, serve as a guide to these impacts in other cities; needed increases in VMT reductions will be about proportional, i.e., if the current 1975 plan calls for x% VMT reductions, Alternative I would require 1.85x%, and Alternative II 2.5x%.)

4b

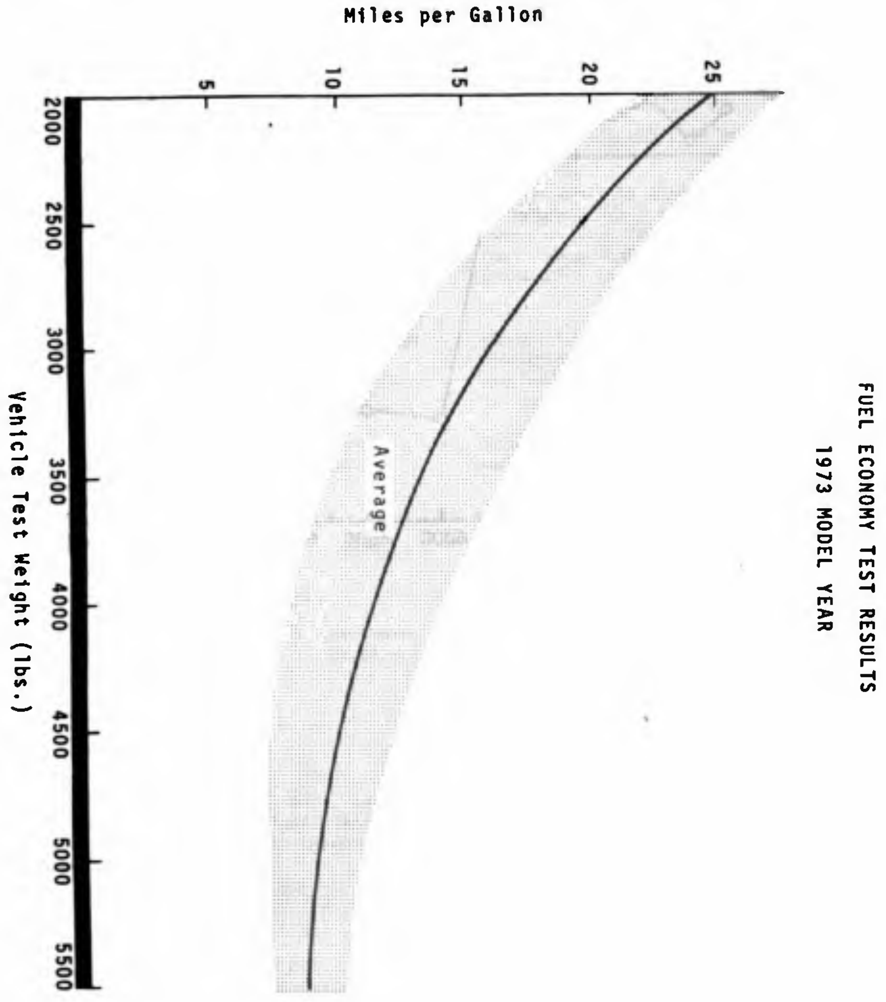
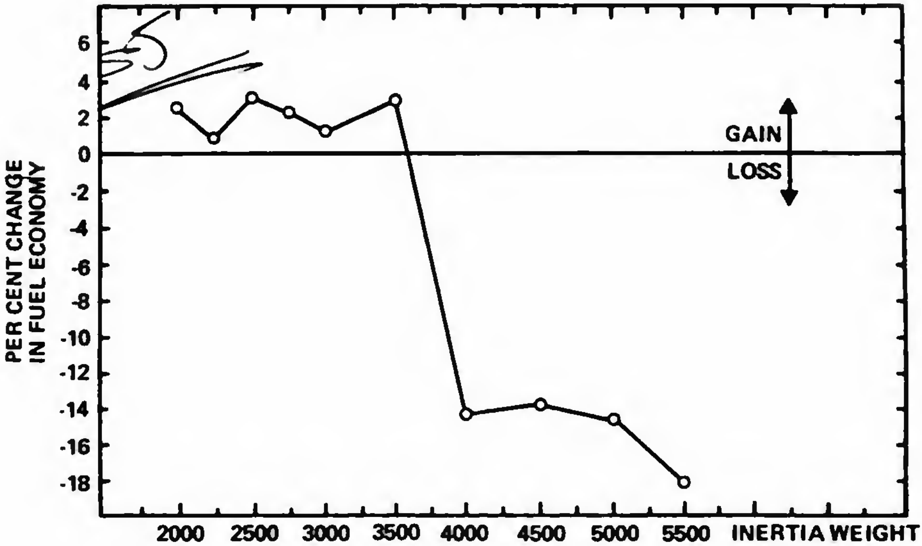

FUEL ECONOMY TEST RESULTS
1973 MODEL YEAR
Miles per Gallon
5
10
15
20
25
Average
2000
2500
3000
3500
4000
4500
5000
5500
Vehicle Test Weight (lbs.)

FIGURE 4
CHANGE IN FUEL ECONOMY
BETWEEN '57-'67 AVE. AND '73 BY INERTIA WEIGHT CLASS



Causes of Fuel Economy Losses on Automobiles

Fuel economy of automobiles is affected by many factors. Gasoline-powered cars in 1974 exhibit fuel economy variations over a range of 4 to 1, i.e., from about 29 mpg to about 7 mpg. The following table identifies the most important design factors that govern fuel economy:

Factor	Fuel Economy Impact
Vehicle weight is the most important factor. 1974 vehicles range from 2000 lbs to over 5500 lbs. Vehicle weight has increased by about 20% since 1962.	Fuel economy is directly proportional to weight, i.e., a 5000 lb car takes twice as much fuel per mile as a 2500 car. About half of fuel economy loss since 1962 is due to vehicle weight.
Air conditioning uses fuel both through use, and through added weight.	9%-20% fuel economy loss when operating, depending on temperature and humidity, and on design features.
Automatic transmissions require more fuel, for weight reasons and because of internal losses.	Losses range from 2% to 15%, depending on the type of transmission.
Compression ratio reduction to permit operation on 91 octane gas.	3.5% fuel economy loss.
Emission controls on 1973/74 cars have varying impacts, depending on vehicle weight.	On small cars (compacts and sub-compacts) there is a slight gain in fuel economy; on large cars there have been losses ranging up to 18%. Sales-weighted average loss for all cars is about 10%.
Emission controls on 1975 cars, to meet the Federal interim standards, will be largely catalytic and will improve fuel economy.	Estimates of fuel economy gains vary. GM estimates average gain of 13%, up to 18% on large cars, over 1973/74 cars. Ford and Chrysler estimate lesser gains.

Mr. Train. I believe copies have been distributed to the committee. This chart, just briefly, illustrates the effect on fuel economy of the emissions standards. The line, the black line through the middle, starting at zero, is the 1973 model vehicle taken as a baseline so that you can see that with the use of catalysts, there is a substantial improvement at 8 percent.

Mr. Sansom. The 1975 interim numbers at the bottom relate to the first two sets, the first two dots there on the chart, and then as you move over, the bottom should be correlated with the black dots at the top. In 1975, interim standards are the 1.5 hydrocarbon, the 15 CO, and the 3.1 NO_x.

This is the line for the catalyst systems right here. This is the baseline, 1973, fuel economy. Putting a catalyst on to meet the 1975 interim standards to be applied nationwide in 1975, as a result of the Administrator's April 1973 decision, would result on a sales weighted basis of an 8-percent improvement in fuel economy. As you move out in this direction, this set of dots—these two here—relate to the California interim standards, which the Administrator has also approved the variance request submitted by California. So the chart is a little off—this goes under these two dots, so you can see for noncatalyst systems, meeting the same standards using a thermal reactor, that you actually have a fuel penalty for the 1975 California standards and an increasing fuel penalty as you move down.

I think you can see here, as well, that as you move out even to the 1976 Federal standards, statutory standards 3.4 CO, 0.41 hydrocarbons, and 2 NO_x, nitrogen oxides, that you still have a fuel economy benefit over the existing performance. But the real penalty you see is related to going from 2 nitrogen oxides to 0.4 grams per mile nitrogen oxide. The Administrator has submitted to you his recommendation that this standard be retained at 2 grams per vehicle mile.

Mr. Rogers. In other words, not go down so you would have a penalty at the end?

Mr. Sansom. That is right. Stick to this point here, rather than going down here.

Mr. Rogers. Then, as I understand it, the top line shows what happens with a catalytic converter?

Mr. Sansom. That is right.

Mr. Rogers. The bottom line shows what happens without the catalytic converter?

Mr. Sansom. Using the thermal reactor in lieu of a catalytic converter.

Mr. Rogers. Are there any other charts now that you want the committee to see?

Mr. Train. There is one other, I believe, under that. This chart, basically, I would take simply to illustrate the impact of weight on fuel economy. Again, the horizontal line is the average of the 57 to 67 precontrolled cars in terms of miles per gallon, and it illustrates that amongst the smaller cars—those are the blue dots at the top there, the car equipped with the 1973 emission control systems, actually have a fuel benefit over the earlier years' uncontrolled baseline vehicles. And this drops off very steeply as you move into the higher range of vehicle weights, up to 5,000–5,500 pounds.

Mr. ROGERS. What would you say is the general penalty associated with weight?

Mr. TRAIN. It is certainly the predominant factor. It is—I was going to say 3 percent, but it is suggested to me that it is probably closer to 2 percent per 100 pounds, something on that order.

Mr. ROGERS. Well, is it about—I had understood, at somewhere around 50 percent of your loss, associated with weight, is that correct?

Mr. SANSOM. Well, I think we have used that number. If you look at the kinds of things you can do to improve fuel economy, what we are saying is—if you did away with the emission control devices on a sales weighted basis, then you might move the cars from 10 miles per gallon to maybe 11; but if you actually switched to smaller cars, you could move it from 10 miles per gallon to 20 miles per gallon.

And if you go the other way, from 20 to 10, that is 50 percent. If you go from 10 to 20, that is 100 percent. The point being, fuel economy is much more sensitive to vehicle weight than it is to emission controls.

Mr. TRAIN. I might make one general observation, Mr. Chairman. The 1975 interim standards are those that have been promulgated by the Administrator so that absent some, either further regulatory action or legislative action, those remain in effect without any further action by the Congress.

The recommendation that we make at this time is that we leave this alone for that 1 year, 1975, period and simply postpone a decision until early next year as to the subsequent years.

In part, aside from the auto emissions aspect of the problem, I think it is very important that Congress act as promptly as it can on the emergency energy legislation which is before this committee. And so, in the interest of moving ahead as rapidly as possible, with that legislation I would think it would be in the interest of that objective to defer matters which can properly be deferred until later, rather than trying to solve all of the possible issues in this particular emergency bill, which obviously is going to have to move ahead with rather short consideration.

Mr. ROGERS. And the basis of that then is because you think the catalytic converter would be required for the 1975 year, the standard will bring a premium in mileage?

Mr. TRAIN. We believe it definitely will provide a substantial fuel benefit. Now, whether all manufacturers will in fact use the catalyst is somewhat open to doubt. General Motors has indicated it would. Ford has indicated it would on a substantial number of cars. I am not certain about Chrysler.

Mr. ROGERS. Thank you.

Mr. Satterfield?

Mr. SATTERFIELD. Thank you, Mr. Chairman.

Mr. Train, I think your suggestion that we defer the things we cannot really measure right now, is a good one.

Mr. ROGERS. I believe the subcommittee shall recess to go to vote. We will then be back to continue with Mr. Satterfield.

The committee will recess for 5 minutes.

[Brief recess.]

Mr. ROGERS. The subcommittee will come to order, please.

Mr. Satterfield was questioning when we had a vote.

Mr. Satterfield.

Mr. SATTERFIELD. Thank you, Mr. Chairman.

Mr. Train, your suggestion that we might defer the 1976 standard, I think is well taken. I would like to address my line of questions to the 1975 interim standards, and why the same observation would not pertain.

First of all, referring to the chart, it would seem to me that the suggestion that there will be a fuel bonus to the owner of a catalytic-equipped automobile would certainly depend upon what happened after the 1975 interim standards. By the chart itself, it is obvious that the bonus decreases markedly if we should go ahead with the 1976 standard. Is that not correct?

Mr. TRAIN. The drop between the 1975 interim and the 1976 Federal standard is only about from 8 to 6 percent, to I believe, 2 to 3 percent.

Mr. SATTERFIELD. Maybe I read it wrong. It looks to me that we are talking——

Mr. SANSOM. The problem is the axis is a little off on the bottom.

Mr. SATTERFIELD. I see.

Mr. SANSOM. But the penalties associated with the .4 NO_x scale——

Mr. SATTERFIELD. But it is a fact that whatever gain you get with a catalytic converter comes about by more efficient operation of the engine; and that if you have to increase your standards beyond that and make the engine operate less efficiently, you are going to consume more gasoline.

Mr. TRAIN. That is correct.

Mr. SATTERFIELD. Now, we are talking about economy under the 1975 interim standard in the automobile's operation, but it seems to me that our real purpose here today is not to talk about that so much as to talk about the overall supply of gasoline and of fuel.

Is it not a fact that the catalytic converter, if it is going to operate and function properly, has to function on nonleaded gasoline?

Mr. TRAIN. Yes, sir.

Mr. SATTERFIELD. Could you tell us then what the penalty of producing nonleaded gasoline as opposed to leaded gasoline would be?

Mr. TRAIN. Looking at the total crude picture rather than the amount of crude used simply to make gasoline, but the total crude picture, I think our largest estimate—and I say that to indicate a very conservative estimate—would be .58 percent of total crude would be required for the production of the necessary nonleaded gas in approximately the first year of this requirement.

Now that assumes, I believe, about a 30-percent pool of nonleaded gas, which I believe we are coming to feel is probably much higher than is realistic. The one year's model car, of course, would represent about 12½ percent of the total automobiles on the road. As we have indicated, only a proportion of these will be fitted with a catalytic converter; and we cannot really state exactly how many, but something certainly less than the whole, maybe around 60 percent or something on that order.

This indicates to us that a 30-percent nonleaded pool factor is excessively high, so that it undoubtedly would be something considerably less than .58 percent of the total pool, probably something closer to .25 of 1 percent.

This is more than made up by the actual fuel savings to the automobile operator from the catalyst itself; so it is not our position that there is any net energy loss from the combined use of a catalyst and the requirement for a no-lead grade.

Mr. SATTERFIELD. Now, are you talking about the first model to have a catalyst on it? Is that what you are saying?

Mr. TRAIN. I believe I have addressed myself to that.

Mr. SATTERFIELD. And that 60 percent of the new models would be equipped with it.

Mr. TRAIN. Perhaps more. Now, I think General Motors has said about 100 percent of their cars, so perhaps closer to 70 percent would be more like it.

Mr. SATTERFIELD. Now, could you translate the first figure you gave us of 5.8 percent penalty. Are you talking about——

Mr. TRAIN. That is .58 percent of 1 percent.

Mr. SATTERFIELD. All right.

Point five eight of 1 percent. Are you talking about the normal supply of gasoline, or are you talking about the projected supply?

Mr. TRAIN. These were 1975 projections, I would assume arrived at prior to the current substantial reduction in supplies.

Mr. SATTERFIELD. And how many gallons would that .58 translate itself into?

Mr. TRAIN. We have got a crude—additional crude—requirement of 90.7 thousand barrels per day in 1975, representing a .58-percent crude usage in order to produce nonleaded gas equal to about 30 percent of the total gasoline pool.

Mr. SATTERFIELD. And how many gallons would that translate into?

Mr. SANSOM. 3.9 million gallons or one-twentieth of a gallon per car per day.

Now, this is just the energy cost of the lead-free regulation. In the fact sheet that you have in the handout on the second page are figures that look at it in net terms; in other words, taking the fuel savings from the catalyst and deducting the fuel cost of removing lead from the lead-free grade of gasoline yields a net benefit in 1977, as you can see.

Mr. SATTERFIELD. You are telling me then that if we take our available gasoline pool now, a substantial sum of gasoline, and make it nonleaded gasoline, that you still expect us to have an advantage at the end of this coming year?

Mr. SANSOM. That is right, if the catalysts go on.

Mr. SATTERFIELD. Do you expect that these catalysts will also be included in the 1976 models?

Mr. TRAIN. Yes. I would suppose, even if the interim standards were continued into 1976 roughly the same proportion of cars would carry the catalyst as in 1975, and if you went to the 1976 statutory standard, quite clearly there would be almost universal use of catalysts.

Mr. SATTERFIELD. Let's assume we do not go to the 1976. Let's assume that the 1975 standard is retained for another year. What percentage of our gasoline pool would have to be diverted then for nonleaded gasoline? You have got a second generation of catalyst automobiles on the road now. It would be more than double, would it not?

Mr. TRAIN. No, sir. It would be substantially less than half. It is my understanding that——

Mr. SATTERFIELD. May I ask half of what?

Mr. TRAIN. Well, half of the first year's crude penalty. And this is true, as I understand it, because in the first year of the installation of substantial no lead refining capacity, there are inefficiencies involved in that near term effort which tend to get eliminated as you move forward. So that in the second and third years you get progressively less crude penalty from the no lead requirement.

Mr. SATTERFIELD. Well, now, we will get back to that.

Mr. TRAIN. Our figures for 1977, for example, again assuming these earlier projections of crude supply drop from 90.7 thousand barrels per day in 1975 to a total of 46.1 thousand barrels per day in 1977.

Mr. SATTERFIELD. Are you predicating this loss on the number of automobiles that are going to be on the road, or are you allocating the loss in terms of how much gasoline you have got to have at all of the different places that you have to have it when you need it to arrive at this figure. Or have you taken into consideration the reserve that will be required if we——

Mr. TRAIN. I think we have tried to take into account all of these factors, Mr. Satterfield; and this is the reason why our very conservative estimate was on the basis of a total no lead pool in the first year of about 30 percent, which would be probably at least three times the lead-free gasoline required by cars equipped with catalysts. And this is designed to recognize that if you are to have a no lead grade sort of universally available for catalyst-equipped cars, you cannot fine tune it down to the actual population. There has to be some surplus.

Mr. SATTERFIELD. And how many gallons of gasoline are burned each year by automobiles in this country now?

Mr. TRAIN. About 7 million barrels of crude per day go into gasoline. Now, somebody is going to have to help me on the math.

Mr. SATTERFIELD. Somebody is going to have to help me, too, because a few minutes ago when we said that 30 percent translated itself into 90,700 barrels, which was 4½ million gallons, and your 4½ million gallons, it is supposed to be 30 percent. There is something wrong.

Mr. SANSOM. I hate to give numbers like this; 7 million barrels, multiply that by roughly 50 gallons per barrel and you get the total gallons of 350 million; 350 million is what I get very quickly; but I would hate to stand by it.

Mr. SATTERFIELD. It seems to me 30 percent is a whole lot more than 4½ million gallons of gasoline, which you testified to a few minutes ago represented the 0.58 percent penalty.

Mr. SANSOM. Now, the 0.58 percent is over the total crude that is passed through U.S. refineries. Half of that goes into the automobile, which would mean if you wanted the percent of the part that goes into the automobile, you would double the 0.58. So it is slightly over 1 percent.

Mr. SATTERFIELD. What I am trying to find out is how many gallons of gasoline are we going to lose by going to nonleaded gas. Now, if you tell me there is a 30-percent penalty, and we are burning 350 million gallons a day, then it looks to me like it is over 100 million gallons penalty.

Mr. SANSOM. Well, the low lead, on the assumptions Mr. Train has outlined, which is 30 percent of the gasoline sold in 1975 would be low lead——

Mr. SATTERFIELD. I am talking about no lead. I am not talking about low lead now.

Mr. SANSOM. I am sorry. No lead, and the penalty associated with producing that is 90,000 barrels a day.

Mr. SATTERFIELD. And how many million gallons?

Mr. SANSOM. Whatever 50 times that is. I guess it would be——

Mr. SATTERFIELD. 450.

Mr. SANSOM. 4.5 million gallons.

Mr. SATTERFIELD. I find it very difficult to reconcile 30 percent at 4.5 million, but I am not going to argue that point any longer.

Mr. SANSOM. But the point, I think, here is that there are two effects that have to be added in together. That is what we tried to do on the factsheet. We tried to add in the cost, the energy cost of producing unleaded gasoline and add to that the benefit that is displayed on that chart over there of having the catalyst system in use.

Mr. SATTERFIELD. But you cannot relate the shortage that way. You can't relate the gasoline loss you have by going to no lead gasoline with the savings in miles per gallon in the automobile. At least you have not as far as I am concerned.

Let's go to something different. Let me ask you this. We are talking about the catalytic converter now. What is the durability of this device?

Mr. SANSOM. Well, we in our regulations have required that the device function for 25,000 miles, which is about 2 to 3 years on a car. General Motors has indicated that their device will last for 50,000 miles, and I think for the life of the car, although I would rather let them speak for themselves on that.

Mr. SATTERFIELD. In a laboratory.

Mr. SANSOM. No; this is what they are planning to do on their 1975 cars.

Mr. SATTERFIELD. Mr. Chairman, are they going to be testifying on that?

Mr. ROGERS. Yes.

Mr. SATTERFIELD. I am going to ask them some questions about that because they testified differently in September.

Mr. ROGERS. I hate to interrupt the gentleman now. If we could go around 5 minutes and come back to the gentleman.

Mr. SATTERFIELD. Very well.

Mr. ROGERS. Dr. Carter.

Mr. CARTER. Thank you, Mr. Chairman.

I believe you state, Mr. Train, that the more a car weighs the more gasoline it will use proportionately, is that correct?

Mr. TRAIN. Yes.

Mr. CARTER. About 2 percent per 100 pounds?

Mr. SANSOM. We have got a chart on that. If you could put the third chart up, it shows that.

Mr. CARTER. Two percent per 100 pounds?

Mr. TRAIN. I think roughly that may be on the high side. I am not sure.

Mr. SANSOM. There is the vehicle weight on the bottom. on the x axis, and the miles per gallon. That is about right.

Mr. CARTER. A 2,000-pound car will go 25 miles per gallon.

Mr. TRAIN. On the average.

Mr. CARTER. That is pretty good, I would say.

I notice that you are pretty strong, or you seem to be, for a catalytic converter; and you state that hydrocarbons and carbon monoxide after they are emitted become carbon dioxide and water, is that correct?

Mr. TRAIN. Yes.

Mr. CARTER. This is in your statement. What happens to the SO_2 which is emitted by the converter.

Mr. TRAIN. By the catalyst?

Mr. CARTER. Yes, sir, by the catalytic converter.

Mr. TRAIN. Of course the cars not equipped with the catalytic converter also emit SO_2 which joins the atmospheric ambient levels of SO_2, some of which eventually gets converted into sulfates, as I understand it.

Mr. CARTER. How eventually is that really? The SO_2, in case there is much moisture in the air, is it not quite readily converted into sulfuric acid mist?

Mr. TRAIN. It could be quite readily; yes.

Mr. CARTER. And this is one of the dangers of the catalytic converters, is that true?

Mr. TRAIN. As I pointed out in tetsifying on the catalyst, the preliminary data indicates that there is some emission of sulfates as a result of the catalyst. In other words, the sulfur oxides are converted to sulfates in the catalytic conversion process and emitted from the automobile at ground level as sulfates, which is the reason for——

Mr. CARTER. Sulfur dioxide really.

Mr. TRAIN. What is that, sir?

Mr. CARTER. Sulfur dioxide, SO_2 in other words.

Mr. SANSOM. What he said is that the existing cars without a catalyst put out SO_2 and over time, 4 to 8 hours in the ambient air contacting with moisture they become sulfates. The catalyst dramatically accelerates that process, and there are sulfates emitted from the catalyst itself.

Mr. CARTER. Sulfates which become sulfuric acid mists in the presence of moisture.

Mr. SANSOM. Yes, sir.

Mr. CARTER. All right.

I believe you stated the catalytic converter has shown or will show a gas savings of 13 percent, is that correct?

Mr. TRAIN. Yes, sir.

Mr. CARTER. To obtain——

Mr. TRAIN. Now, that is the high estimate given by General Motors.

Mr. CARTER. All right, sir.

Mr. TRAIN. Other estimates are somewhat lower, and I believe we accepted about 7 percent.

Mr. CARTER. Seven? Some even lower than that, under 2 or 3 percent?

Mr. TRAIN. Some have said 2 or 3 percent, but I believe this takes into account only their catalyst-equipped cars. I am not positive of that fact, and you might want to ask their witnesses when they come before you to explain those differences.

Mr. CARTER. What penalty do we pay for obtaining unleaded gasoline in refining crude oil?

Mr. TRAIN. Well, according to our computations, there would be somewhere between 0.25 percent and 0.58 percent of total crude penalty to provide the first year's supply of no-lead gasoline that the——

Mr. CARTER. Of crude, 0.25 percent of crude.

Mr. TRAIN. And that there is, however, a net benefit because of the gasoline savings in the automobile from the use of the catalyst which is made possible by the availability of the no-lead gas.

Mr. CARTER. Yes, sir. Even with the no-lead gas, then you would get a 13-percent increase in mileage with the catalytic converter, is that correct?

Mr. TRAIN. Somewhere up to that figure, yes.

Mr. CARTER. Yes, sir.

I notice you mentioned unacceptable levels of lead in the blood. What are acceptable levels?

Mr. TRAIN. I understand that there is a clinical standard of 40 milligrams——

Mr. SANSOM. Forty micrograms.

Mr. TRAIN. That sounds more like it, 40μg of lead per 100 ml of whole blood, above which clinically observed adverse health effects, particularly brain damage, are observed, so that would seem to be sort of clinically a threshold.

Mr. CARTER. Could I obtain the source of your information on that if you please, sir? I feel certain your information is grossly incorrect.

Mr. TRAIN. If I may submit that for the record, I would be very happy to do that.

Mr. CARTER. All right, sir.

[The following information was received for the record:]

BLOOD LEAD LEVELS

1. The U.S. Public Health Service recommended in 1971 that, for older children and adults, until proven otherwise by additional research, ". . . a blood lead concentration of 40 μg or more per 100 ml of whole blood, . . . determined on two separate occasions, be considered suggestive of undue absorption of lead, either past or present." (1) This recommendation also established 80 μg/100 ml (100 gm) as requiring immediate evaluation of as a potential poisoning case.

2. This 40 μg of lead/100 ml (100 gm) of whole blood has subsequently been accepted as evidence of undue exposure to lead in children and adults by the National Academy of Sciences (2). Excretion of urinary delta aminolevulinic acid (ALA-U) begins to increase as blood lead content rises above a level of 40 μg of lead/100 gm of whole blood. Such an increase in ALA-U is generally considered indicative of biochemical changes in the tissues that are undesirable and physiologically significant (3). Further discussion and references are given in Chapters III. Health Aspects of Lead Exposure, and IV. Can an Acceptable Lead Body Burden be Defined?, in the document, "EPA's Position on the Health Implications of Airborne Lead," U.S. Environmental Protection Agency, November 28, 1973.

3. The level of 40 μg/100 ml or 100 gm of blood does not represent a sharp demarcation between health and disease; it does, however, represent a level which is considered to be biomedically undesirable and cause for clinical concern regarding undue lead absorption.

References for Testimony of the Administrator, EPA, before the House Subcommittee on Public Health and the Environment, December 3, 1973, pp. 25, 26.

1. "Medical Aspects of Childhood Lead Poisoning," HSMHA Health Reports, 86(2); 140–143, 1971.

2. "Airborne Lead in Perspective," report prepared by the Committee on Biological Effects of Atmospheric Pollutants, Division of Medical Sciences, National Research Council, National Academy of Sciences, Washington, D.C., 1972, pp. 100–110.

3. Airborne Lead in Perspective, op. cit., p. 110.

Mr. CARTER. What are acceptable lead levels in the ambient air?

Mr. TRAIN. That is not an easy question to answer. I think by one way of looking at it you would say that we would prefer to have no lead particles in the atmosphere, all things being equal, so that I would think, as in many cases, a risk-benefit equation has to be struck here, weighing the health impacts with the supposed social benefits of having lead in automobile fuels.

Mr. CARTER. We are setting lots of standards these days and we are talking a lot about lead, about these other standards, NO_x, carbon monoxides and hydrocarbons, and yet we say that lead is a very dangerous substance, but as yet we have no standards for lead in the ambient air.

Of course, it would be a consolation, devoutly to be wished if we had neither carbon monoxide nor lead in the air.

Mr. SANSOM. We sought in our initial proposed rulemaking to reduce the amount of lead in gasoline, to set it on the basis of an ambient standard of 2 micrograms per cubic meter, which is exceeded in, I think, well over 20 cities in the United States. But our medical people advised us that the more straightforward approach would be to reduce the lead that is emitted in the air, which we also have the authority under the Clean Air Act to do without setting an ambient standard, because some people if they were right at the margin and inhaled lead from air in which the ambient concentration was less than 2 micrograms, still might be pushed over the threshold. In other words, we could not relate a threshold health effect to the ambient air concentration of land, so rather, we took the course of reducing the lead emissions.

Mr. CARTER. I find it rather ambiguous that you would set a level of 2 micrograms per cubic meter in the ambient air.

Mr. SANSOM. We didn't.

Mr. CARTER. And go as high as 40 or even suggest that, and go as high as 40 micrograms per cubic meter in the human blood.

Mr. SANSOM. We did not set that level. In fact, we withdrew that.

Mr. CARTER. Well, you brought it up. What did you say about it? Would you repeat yourself on that? I give you that liberty.

Mr. SANSOM. Well, I wanted to point out that we failed in our effort to say there is a threshold in the ambient air at which lead becomes a vanguard, so we, as Mr. Train said, want to reduce all the lead in the ambient air.

Mr. CARTER. Well, certainly I would like to reduce all lead in the blood in the human body, too.

Thank you, Mr. Chairman.

Mr. ROGERS. Thank you.

Mr. Kyros?

Mr. KYROS. Thank you, Mr. Chairman.

Mr. Train, suppose, since we are talking about saving gasoline and we are worried about stocks of gasoline, that you took all existing pollution devices and control systems off and just tuned all engines to maximum efficiencies?

What savings would you say then would occur in gasoline, just assuming those factors?

Mr. TRAIN. Now, you are assuming that can be done.

Mr. KYROS. Yes; assuming that can be done.

Mr. TRAIN. Let me say first, our very firm belief is that it cannot be done, but if you could do it you would get rid of the 10 percent roughly on the average fuel penalty that we believe the present generation of emission controls provides, but it is quite plain that you cannot just simply disconnect emission control devices on existing cars. It is not just a matter of having a gadget somewhere on the car that can be removed. The emission controls are built in to the entire automotive system and would involve completely rejiggering the entire machine.

I know that our own engineer-scientists at Ann Arbor to satisfy their own scientific curiosity—I hope it was only scientific curiosity—endeavored to disconnect automotive emission control devices on their cars. To the extent they succeeded, I believe, in almost every case their tinkering resulted in worsened fuel economy.

I think it is fair to say that this is not an avenue for resolving the energy problem. Frankly, based upon my own personal experience with garage mechanics around the country, I shudder at the thought of having all of the automobiles now on the road having to go in and get their automotive emission control systems adjusted in the kind of fashion you are talking about. I don't really think we will achieve any very useful result.

Mr. KYROS. What would the impact be if you did that on air quality?

Mr. TRAIN. The impact on air quality would be very substantial in terms of increased emissions of hydrocarbons, carbon monoxide, and nitrogen oxide.

Mr. KYROS. What about transportation control?

Mr. TRAIN. Well, to put it briefly, I guess you could say you would put all the transportation controls into a cocked hat. It is an old expression that I grew up with. I think it is still fairly descriptive. The transportation control strategies that we have developed for various communities around the country, and many communities have developed for themselves, assumed the statutory emission control standards. To the extent those standards are relaxed—and I might point out that even a continuation of the 1975 interim standard beyond 1975 will have this effect—to that extent, the transportation plans presently promulgated will no longer be adequate to meet the standards and in theory at least would call for further constraints on vehicle miles traveled.

Mr. KYROS. So in fact you feel that removal of such emission control systems would result in a deterioration of public health. You do not want to pursue this avenue at all.

Mr. TRAIN I do not think there is any question about it. That is the purpose for which the automotive emissions standards were set.

Mr. KYROS. What about on new cars? Are there not other ways to improve fuel efficiency or economy, rather?

How about requiring the use of radial tires?

Does that make any difference?

Mr. TRAIN. Yes. Radial tires are a substantially more efficient type of tire in terms of fuel use.

Do we have a figure on that?

Mr. SANSOM. It is about 5-percent improvement on radial tires.

Mr. KYROS. Five percent, that high?

Mr. SANSOM. Yes.

Mr. KYROS. What about requiring a phased weight reduction, for example, 500 pounds per year over a period of 5 years?

What would you think of that?

Mr. TRAIN. There are a great many things that are involved here, and I think it is useful to mention some of them, just to keep the emissions aspect in perspective.

You have mentioned the tires. Air-conditioners on automobiles involve around a 14 percent fuel penalty. The power transmission——

Mr. SANSOM. This is on the handout. It is on the last page of the handout that you have.

Mr. TRAIN. The automatic transmission losses ranged from 2 to 15 percent, depending upon the type of transmission. The vehicle weight is undoubtedly the most important single factor. The 1974 vehicles range from 2,000 pounds to over 5,000, vehicle weight having increased about 20 percent since 1962.

Fuel economy is directly proportional to weight, and that is to say a 5,000-pound car takes twice as much fuel per mile as a 2,500-pound car.

To follow up on the direction in which I hope perhaps your questioning was leading, if I may anticipate, it seems to me that it is in these areas where we should first turn, to which we should first turn to seek energy savings before we start relaxing health related emission standards. I think that is very plain.

Mr. KYROS. Would you put in regulations requiring a phased weight reduction over several years in the future?

Mr. TRAIN. I think this is something that should be looked at very carefully, and speaking personally, I would like to see us move in this direction.

Now, whether it should be purely on the basis of weight, or whether we should seek a miles per gallon standard, for example, I think would be open to question. One could have a miles per gallon standard with an average set, leaving considerable flexibility as to how one arrived at that particular figure. Some vehicles, perhaps, would have more weight and less of something else.

Mr. KYROS. How about power windows, power seats, other optional features in automobiles?

Do they all require added fuel?

Mr. TRAIN. These, of course, all do require added fuel. I am not sure how significant these so-called convenience devices are, but they all do add up to the fuel penalty.

Mr. KYROS. Well, do you think that it would be a greater social utility, perhaps, to boost fuel economy by approaching these methods than by reducing air pollution control emission standards?

Mr. TRAIN. Absolutely.

Mr. KYROS. Thank you, Mr. Train.

Thank you, Mr. Chairman.

Mr. ROGERS. Mr. Hastings?

Mr. HASTINGS. Thank you, Mr. Chairman.

Mr. Train, I am not sure I got the answer to the question that Mr. Satterfield put as to what is the actual loss in refining of no-lead gasoline?

Now, if you do not have the figures, if you would supply them it would be extremely helpful.

Mr. TRAIN. Well, we do have the figures.

Mr. HASTINGS. Now, we talked about crude oil at one point. I am talking now about in the refining process of gasoline, what is the actual loss in that refining process?

Mr. TRAIN. The figures I gave were for the total crude pool. Gasoline represents about half of that. So there could be with respect to that portion of crude used for the production of gasoline, about a—as high as a 1-percent approximate crude penalty.

Mr. SANSOM. And the other thing Mr. Train pointed out is that over time that penalty is reduced as the refineries have the time to install more efficient tracking devices on their refineries.

Mr. HASTINGS. Now, on that point, now, is it not an EPA policy already, or instructions, that the oil refineries must by 1974 go to an unleaded gasoline in a certain amount of their production?

Mr. SANSOM. That is right, but I think they——

Mr. HASTINGS. Well, are they in a position to proceed with that at this point?

We heard a lot of noise from some oil companies saying they cannot. We are a little bit concerned because I thought they were under that directive already.

Mr. SANSOM. Well, they are, but I think there is a period here where they have to make the investments and design the changes in the refineries, and I think they are doing that. And what we are saying is——

Mr. HASTINGS. What was the date of the original order? Was it not by 1974?

Mr. SANSOM. That is right, by mid-1974.

Mr. HASTINGS. That is not very far away, and you say they have yet not made the capital investments or the plans to proceed with the production of selling nonleaded gasoline?

Mr. SANSOM. I think they have made the plans, but they had the choice of either using a technique that required a little bit more crude, or making a change in the refinery, and we did not tell them which of those two directions to go in, and it appears that some of them, based upon this model we have used to estimate fuel costs, have chosen to go without the modification in the refinery, at least in the near term, and use more crude in the refinery process instead. It is a tradeoff.

Mr. HASTINGS. But the current situation shortage could affect that of course.

Mr. SANSOM. We would hope that it accelerates the pace at which they make these changes in their refineries, and over time it will reduce the crude penalty associated with——

Mr. HASTINGS. Let me ask a couple of basic questions.

Mr. TRAIN. Could I just make one point?

These figures, although we like to speak with full confidence about them, there has been a great many variants, variations in data presented by various witnesses before the committees of the Congress on this subject.

Mr. HASTINGS. Well, how about before EPA? They have all testified in front of you, too, I understand.

Mr. TRAIN. Well, we have confidence in our figures. We have used outside consultants, thoroughly familiar with the petroleum industry, and I believe the figures that I have given you are conservative, and I have tried to so indicate. I just wanted to point out as to indicate the wide variance in estimates. This letter from Mr. Cole, of General Motors, to the chairman of the Senate Public Works Committee, dated November 27, states, "We understand from a recent study by Arthur D. Little, Inc., that on a nationwide basis, up to 50 percent of gasoline production could be made unleaded at 91 RON (research octane number, and 83 RON."

I am not positive what that initial means.

Mr. SANSOM. Motor octane number.

Mr. TRAIN. "Without a crude oil utilization penalty."

Mr. HASTINGS. Do you think that is an accurate figure?

Mr. SANSOM. I think the point is that we had this contractor develop a model. He has gone back over it three times. It has been under very heavy attack. He continues to stand by the results. There are other studies, like this one, that indicate we have overestimated the crude penalty. I am sure there are even other ones that say we have underestimated it.

Mr. HASTINGS. On my second 5 minutes around, I will expand on this, but there are a couple of basic items I would like to get in perspective.

You are saying you do not want any changes now whatsoever.

Mr. TRAIN. In the 1975 interim standards, right.

Mr. HASTINGS. You do not want us to change in the Emergency Energy Act which the full committee is considering, or to consider a change in the Clean Air Act related to auto emissions standards. Correct?

Mr. TRAIN. This is correct.

Mr. HASTINGS. And even if we were to accept your recommendation or go to the 1975 or 1976, 1977, that still would say to manufacturers they must go ahead with catalytic converters?

Am I correct under either one of those situations?

Mr. TRAIN. Well, the 1975 interim standard was set by EPA in the belief that it was a standard which could be met without the use of a catalytic converter on a wide basis.

Now, despite that conclusion on EPA's part, as you know several manufacturers have indicated an intention to use catalysts, presumably because of the better engine performance.

Mr. HASTINGS. Well, from a practical point of view, though, am I not correct that it will probably say they will have to proceed, I will just say practically?

Mr. TRAIN. I think that on the basis—practically speaking, on the basis that you put the question in 1975 model year, you get about 100 percent of General Motors cars and about 60 or 70 percent of the other two. Now, but you may have a sliding off on this in the subsequent years.

Mr. HASTINGS. Let me turn that around.

If we were to go to standards, say 1974 standards, which some people feel we ought to take a look at it, and catalytic converters probably would not be required on those 1975 model years.

Is that correct?

Mr. TRAIN. Yes.

Mr. SANSOM. Definitely not.

Mr. TRAIN. And you would get a very substantial fuel penalty.

Mr. HASTINGS. Which may very well be a part of the argument we are confronted with as we try to make any change in the Clean Air Act, and I think, of course, we all recognize that. And then of course there is the leaded gasoline situation.

Incidentally, what is the cost of conversion? I have seen figures as high as $40 billion, which is in contrast to the figures Mr. Cole presented to convert, to produce that amount of unleaded gasoline by 1975.

Mr. SANSOM. I think we have in the lead fact sheet, in the handout, an estimate of the cost to the consumer of the unleaded grade, which is a 0.4 cent per gallon, or $13 for a car driven 40,000 miles.

Now, the fact sheet goes on to point out that because lead damages the sparkplugs and the exhaust system and so on, that the consumer—we say this on top of page 4—will probably realize a net monetary savings.

Mr. HASTINGS. My question was to the refineries, though, the refinery process. What amount of dollars would that be—there have been figures, I say, as high as $40 billion in making the changeover, and I just would like to know whether they are accurate or not.

Mr. SANSOM. As high as how much?

Mr. HASTINGS. $40 billion.

Mr. SANSOM. No, it's less than $100 million, but I do not have the figure right here.

Mr. HASTINGS. Well, if you would supply that.

Mr. Chairman, I have gone beyond my 5 minutes, and I relinquish my time.

[The following information was received for the record.]

REFINERY INVESTMENT—LEAD REMOVAL FROM GASOLINE

EPA's best estimate is that the combined impact of the lead-free and low-lead regulations will be to increase refinery investment by less than 1 billion dollars by 1980.

This estimate is extremely soft because the model that was used to estimate the economic and energy impact of the lead regulations is based on a 1970 or 1971 refinery survey. The refinery industry has been continuously upgrading its existing facilities and a number of the changes which the model assumed were necessary to reduce the impact have already been made. Therefore, we believe that the $1 billion estimate may be high.

Mr. ROGERS. Mr. Preyer.

Mr. PREYER. Thank you, Mr. Chairman.

Mr. Train, I think we in earlier hearings heard a lot about the use of the stratified charge engine, the Honda engine, and the evidence was very encouraging as to how this engine would perform in meeting the clean air standards.

The question I would like to ask you about that engine relates to its fuel economy performance.

Do you have any estimate or way of comparing the fuel economy performance of a stratified charge vehicle with a comparable catalyst vehicle, meeting identical standards?

Mr. SANSOM. We have tested the Honda CVCC engine on an Impala at our laboratories and found that it met the standards, not the nitrogen oxide standards but the statutory 1976 standards, the 3.4, .41, I think at roughly the fuel economy that is experienced by today's cars.

Now, we also hear quite frequently—and it is very difficult to pin this down—that there is the potential in the stratified charge engine for achieving fuel economy benefits of up to 30 percent. I have heard that very recently.

We intend to prefer to go on the basis of data we have gotten from tests in our laboratories, and as of right now we would say the stratified charge engine has roughly the same fuel economy as today's car, but that is just one test in one car, and we think and I think our engineers believe that there is a potential for much larger fuel benefits from the stratified charge.

Mr. PREYER. One of the arguments for delaying any change in the standards, for freezing the standards through the 1977 model year, I would suppose, is that it would give you a chance to develop the stratified charge engine, and you might be able to skip the generation of catalyst converter cars.

Mr. TRAIN. I am not sure that the incentive would work that way. I think that is open to question. A number feel that freezing of the level is going to be an incentive for staying there we are rather than moving ahead, and I think this is undoubtedly one of the considerations to keep in mind. Other things being equal, progressively higher standards do give rise to a strong incentive for exploring and developing alternative systems, power systems, and I really do believe the extent that we freeze these and maintain a constant level, it would act as a disincentive to that objective.

Mr. PREYER. That is a very good point. I would like to quote Dr. Johnson to the effect that if a man knows he is going to be hung in a fortnight, it concentrates his attention wonderfully. I think we would want to make sure the automobile companies' attention is concentrated on cleaning up our air.

Well, along this same line, how long would it take to retool the entire automobile industry to produce stratified charge engines 100 percent?

In other words, how far away is this?

Mr. SANSOM. I think the 7 to 8 years for 100 percent, if they were to launch themselves on a program right now to put the stratified charge engine or the diesel, for that matter, that sort of change in technology, and they would have perhaps some of them in, maybe a million out of the 10 million by 1977, and then they would have to phase them in after that over the following say 4 to 5 years.

Mr. PREYER. So during this period you would say that the catalytic converter looks like the kind of controls we would have to use.

Mr. SANSOM. That is right. The only other near term option is the thermal reactor, which has very poor fuel economy. That might be possible in a little nearer time frame.

Mr. PREYER. If I could ask just one more question on a different subject, Mr. Chairman.

Mr. ROGERS. Certainly.

Mr. PREYER. Mr. Hastings raised the point that some people have said if we stay with the 1974 standards, then we would not even need the catalytic converter. There was an article in the Washington Post this morning which described the kind of transportation controls that might be necessary if we did something like that, and I wanted to ask you if it was accurate.

It quoted an EPA official who said that a lot of cars would have to be kept off the roads to achieve the goal for healthy air in cities like Washington. The goal for the Washington area requires a 13 percent reduction in vehicle traffic if the Clean Air Act standards are imposed on 1976 model year cars, and a 24-percent reduction if the interim standards for 1975 are kept intact throughout the 1977 model year.

Is that about accurate?

Mr. TRAIN. That is correct for the Washington area.

Mr. PREYER. Do you have any idea what it might be if we kept the 1974 standards?

Mr. TRAIN. I think there would have to be about, according to the data I have before me, about a 32 percent reduction in vehicle miles traveled instead of just 13 percent, almost three times as much.

Mr. SANSOM. To help you, generally the total reduction in tonnage of emissions that is necessary to achieve the standards in the Washington, D.C. area, 70 percent of that reduction will be achieved by new cars coming into the fleet. In other words, the emission standards have very high leverage on the traffic reductions required to meet the standards.

Mr. PREYER. This would seem to be a pretty good argument against the 1974 standards.

Thank you.

I yield my time.

Mr. ROGERS. Mr. Heinz?

Mr. HEINZ. Thank you, Mr. Chairman.

Mr. Train, I would like to return to the question that Mr. Satterfield and Mr. Hastings were touching on, which is the fuel penalty associated with the shift to low lead and unleaded gasoline. I am not a physicist, but I seem to recall that there is an item called the British Thermal Unit, and in any barrel of oil I understand there are only so many of them and that you cannot change the number of Btu's in a barrel of oil. You may make the conversion of those Btu's more efficient by the particular kinds of mechanisms and we in fact have several ways of utilizing them, gasoline is one, residual fuel oil is another, home heating oil is a third.

When we are talking about refinery penalties, just what is it we are talking about when we, in order to get gasoline of a given octane, have to, without using lead or using low lead, what is causing the penalty at the refinery since the Btu's do not disappear.

What is going on at the refinery, so we understand that?

Mr. SANSOM. I would be the first to say I am not an expert in this area, but you are right. It does not disappear but it takes more energy to get the barrel of crude through the refinery and into the octane level that you want, so you are consuming.

Mr. HEINZ. They have to apply more heat in the cracking tower to get the smaller fraction.

Mr. SANSOM. That is right, and we have netted out the benefits of the other butane, isobutane, and so on, that are produced, other by products that are increased as a result of this process.

Mr. HEINZ. So the penalty that you mentioned, which—the original figure of .58 percent, does not square with the numbers you gave us later. You gave us 4½ million gallons of gasoline a day as the penalty on a base of 350 million gallons of gasoline that were used per day, which works out to a little more than 1 percent. I had a little trouble reconciling the .58 percent with the 1 percent plus.

Mr. SANSOM. The difference is that the .58 is overall crude that goes into the refinery. The 1 percent is over half the crude that comes out as gasoline. So if you look at it solely in the automotive sector, then you have doubled the percentage.

Mr. HEINZ. I see. All right, do you believe that the Government should play any role in the development of a cleaner and more efficient engine? Should we require, or authorize NASA, to do some development work on a cleaner, more efficient engine?

Mr. TRAIN. I think the Government does have a role, very definitely. It is a question of what that role is and how big a role. The Government has taken its role to be one of providing incentives and encouraging, primarily research and development by private industry in this area and primarily by setting regulatory standards, to create the incentives for developing the alternative systems.

We have, through our own research programs headquartered in Ann Arbor, sought to develop at least two alternative power systems, and not with a view that this was necessarily going to solve the problems of automotive emissions, but to provide an incentive for private efforts.

Mr. HEINZ. All right.

Mr. TRAIN. But it has been fairly modestly funded at the level of around $9 million a year or something on that order.

Mr. HEINZ. Do you feel additional funds would be helpful or necessary?

Mr. TRAIN. Well, as a bureaucrat, I would say that additional funds are always—would always be helpful.

Mr. HEINZ. I should not have asked.

Mr. TRAIN. I did not clear that statement.

Mr. HEINZ. All right. Returning to the refinery penalty just so that we do come to the conclusion. The penalty would be in the nature of one-half to 1 percent, depending on which base you take and——

Mr. TRAIN. I think it really is a maximum. We see it that that is the top level, it would be something less than that.

Mr. HEINZ. And my understanding is that if you would go to catalytic converters, that that penalty would be offset, more than offset—substantially more than offset—by the gains in efficiencies by using a catalytic converter, which comes about presumably because you do not put on, therefore you do not connect, some of the existing blowback devices that I guess decrease automobile engine operating temperatures? Do they increase or decrease it?

Mr. SANSOM. They decrease.

Mr. HEINZ. They decrease?

Mr. TRAIN. Yes, decrease, that is right.

Mr. SANSOM. But on your numbers, you said—double the .58 percent for 1975. The figure for 1977 would be .54 doubled. In other words, the number goes down over time because of this phenomenon we discussed earlier. And then as you get down to 1980, it would be .14 percent.

Mr. HEINZ. I thank you both, very much. Mr. Chairman, I have to go vote—the best 5-minute rule you could possibly have.

Mr. HUDNUT. We are not—we are going to keep going and not recess, Mr. Chairman?

Mr. SATTERFIELD [presiding]. About 2 more minutes.

Mr. HUDNUT. Well I want to ask one very simple question because a lot of these charts and the technical language are important for the sophisticated people in this room, myself excluded, because there is a lot, frankly, I do not understand. But I do talk to the man on the street who feels very strongly—whether rightly or wrongly—that because of the emission control devices on his new automobiles that he is buying, he is getting less gas mileage than he used to.

I would like to ask you, first of all, whether or not you feel that assumption of his is scientifically valid; and second, I would like to ask your opinion about what you would think with reference to legislation that would repeal the penalty in the Clean Air Act that now makes it a Federal offense for a dealer or a manufacturer to disconnect the emission control device.

Mr. TRAIN. Well, first let me say that the average citizen is quite correct in his scientific judgment or his engineering judgment or his intuitive judgment, that he is getting less gas mileage with automobile emission control, assuming he is driving a large car, or one of the larger cars. If he is driving a smaller car, at the smaller end of the spectrum, he should be getting better gas mileage.

But assuming most Americans still do drive medium-sized and large cars, I think it is a fair conclusion that he is getting poorer gas mileage in his current model than he did precontrol. This should be substantially eliminated, that penalty, by going to the 1975 interim standards with the catalyst.

On the second part of the question, I would like to ask Mr. Sansom to answer briefly.

Mr. SANSOM. Yes, I think one of the ways for the nonsophisticate to understand this is that we had an individual in the State of Florida who had an automobile and was convinced that he was getting worse gas mileage——

Mr. SATTERFIELD. I wonder if the gentleman would suspend at this point and complete his answer when we come back, we have only got about 5 minutes to make the vote. The committee will stand in recess.

[Brief recess.]

Mr. ROGERS. The subcommittee will come to order.

I think Mr. Hudnut was in the process of asking questions, and getting some answers. As I understand, he should be back shortly, and I will let him finish his questioning.

In the meantime, I have a question or two I would like to ask. Would you like to finish your answer, Mr. Sansom?

Mr. SANSOM. Yes. The question was twofold. One, the layman's impression is that emission devices have caused the fuel penalties. That is right, in layman's terms. And second, the act does have penalties in it for dealers who disconnect emission control devices and should those penalties be sustained.

Mr. Train answered the first part, and I was to answer the second. And I want to link it to one event that relates to the first as well, that is one of the two cases we have under the law pending where there has been a violation, a dealer disconnecting a device in the State of Florida. A car owner came in with his car, and said that it was suffering from poor fuel economy, and would the dealer disconnect the emission control devices and correct it.

It turned out that the emission control device was disconnected, but the fuel economy got worse. And I think the point of this is while the perception of declining fuel economy is an accurate one the cause is not altogether clear.

Mr. Train mentioned earlier that average vehicle weight has been increasing, and for some makes of cars, average vehicle weight has gone up 500 to 800 pounds over the last 5 years. And so an individual might be buying the same make of car and suspect that the penalty is due to emission controls, when in reality it is due to the increasing weight of that same car.

With regard to the second part of the question, I think that——

Mr. ROGERS. Now, just a minute. I see Mr. Hudnut approaching. So if you will suspend one moment, we will get him in here so he can hear the last part of your question.

Mr. SANSOM. I wish I had more to offer.

Mr. ROGERS. Mr. Hudnut, I think you were in the midst of questioning. Mr. Sansom has given us a summary of what he was saying. You may proceed, Mr. Sansom.

Mr. SANSOM. In the second issue of the desirability of relieving that part of the legislation that has penalties in it for people, dealers, who disconnect emission devices; I think we would feel very strongly that that section of the law should be retained, and if anything, strengthened to possibly go to the individual consumer as well.

Mr. HUDNUT. Thank you, Mr. Chairman.

Mr. ROGERS. I understand we have got another vote. First, I want to ask Mr. Train a question. It was mentioned earlier that there was a proposed amendment, which I think had been worked out with perhaps the Energy Office and possibly someone in the White House too, suggesting that there be a postponement of 1975 or rather an extension to 1977.

I think you are aware of that, and I wonder if you might like to clarify for the record any statement that you think would be helpful as far as the Agency's position.

Mr. TRAIN. Well, I think it is clear from my testimony, Mr. Chairman, that EPA's position at this time is that there should be no action with respect to 1976 and 1977, that it is not necessary, and that this could well be postponed, deferred until early next year, when we have more facts before us.

There is no need to take those steps now; to that extent, I would guess that my views are at variance with the language that has been submitted to the committee, which you have referred to. I am not aware of the source of that language. I am not sure whether it was the Office of Energy Policy or not.

Mr. ROGERS. I am not certain of that either.

Mr. TRAIN. But it clearly does not represent our views at this time.

Mr. ROGERS. Yes.

Mr. HEINZ. Would the gentleman yield for one question?

Mr. ROGERS. Yes, certainly.

Mr. HEINZ. Mr. Train, were you consulted by anybody with respect to the proposal that the chairman was referring to? Was your Agency consulted in advance at all?

Mr. TRAIN. No, sir.

Mr. HEINZ. Thank you, Mr. Chairman.

Mr. ROGERS. I presume we will hear from the people Wednesday, from the Energy Office and perhaps from the Advisory Council. We will go into this with them.

Now, has your statement been cleared by the Office of Management and Budget for today?

Mr. TRAIN. I believe so. I see confirmatory nods from my associates. I believe that is a safe statement.

Mr. ROGERS. Yes.

Now, it is my understanding that New York State has done quite a job with an automobile, and I want to get your evaluation of it. A 1972 Matador that has been tested by the Environmental Protection Agency in Ann Arbor, Mich.; it is my understanding this car has 25,000 miles on it, and seven tests have been made.

It performs under the 1976 standards, and it is my understanding that it has used current technology. And the car on an 800-mile run, driven in five lengths at 60 miles per hour, got an average of 17 to 20 miles per gallon.

Is that about correct? Perhaps you can put something in the record for us, but please give us a quick comment right now.

Mr. TRAIN. I am going to ask Mr. Eric Stork, who is the head of our Office of Mobile Sources, to comment on that.

Mr. STORK. Mr. Chairman, we have completed the tests on the Balgord car, the technology——

Mr. ROGERS. I think this is most significant, and I also want to hear what you are saying.

Mr. STORK. I am sorry. Am I not speaking loud enough?

We have completed the tests on the Balgord car, and the technology used is essentially similar to the technology that was considered at the suspension hearings on the 1976 standards last spring.

The conclusion that our technical staff draws from this series of tests is that the approach, the dual catalyst approach, is indeed one that is worthy of further development. However, the tests on this particular experimental car in no way change the technical data base on the basis of which EPA last spring concluded that meeting the 1976 standards, the .4 grams per mile NO_x is not now technically feasible.

Mr. ROGERS. Although I believe this car does fall below the .4, does it not, in the tests?

Mr. STORK. At 25,000 miles, one test was at .4, one was below, one was above. The catalyst showed very significant deterioration from 0 miles. It was one-fourth of the standard at 0 miles. We have the test report available for you, if you want it.

Mr. ROGERS. I think that would be helpful to have. Do you find there has been a saving in mileage?

Mr. STORK. No, sir. Compared to a similar 1973 American Motors car, there was an 11-percent loss in fuel economy for this car, which is not surprising because the car has to run rich. In terms of the average of the weight class in which the vehicle was tested, the loss was somewhat less, but there is always a scatter of fuel economy results within any given weight class.

So comparing it to a sister car, it is about 11 percent less.

Mr. ROGERS. That is a penalty, then?

Mr. STORK. A penalty, sir.

Mr. ROGERS. But it does meet the air standards?

Mr. STORK. It just barely met the standard at 25,000 miles. The other thing——

Mr. ROGERS. Which standard, 1967?

Mr. STORK. Yes, sir.

Mr. ROGERS. Well, that is better than any of the others, is it not?

Mr. STORK. No, sir. Essentially similar results have been achieved with other kinds of systems, which were considered at the suspension hearing. But all of them are far from being ready for production, and also suffer fuel economy penalties.

Mr. ROGERS. Well, now what cars met 1976? I was not aware of that. I thought even the Honda could not do that on the NO_x?

Mr. STORK. For example—well, the Honda, the small Honda car, has shown the capability to meet the 1976 standards.

Mr. ROGERS. Even the NO_x?

Mr. STORK. Yes, sir, but not with the large Impala conversion. I cannot think of the company's name at the moment, a muffler company that made the so-called reverter, which is a very rich operating type of device, was able to meet the 1976 standard, but with a very substantial fuel economy penalty.

Mr. ROGERS. I think it would be well for us to have those tests put

[Testimony resumes on p. 41.]

[The information referred to follows:]

EVALUATION OF THE NEW YORK STATE DUAL-CATALYST VEHICLE—NOVEMBER 28, 1973

(Test and Evaluation Branch Emission Control Technology Division Environmental Protection Agency)

BACKGROUND

Dr. William Bulgord of the New York State Department of Environmental Conservation contacted the Emission Control Technology Division to request low mileage evaluation of a dual catalyst control concept. Testing of the vehicle was arranged and conducted in June of 1973. Subsequent to this evaluation the vehicle was returned to New York State personnel for mileage accumulation. After compiling approximately 25,000 miles on the dual catalyst system, Dr. Balgord again brought the vehicle to the EPA Ann Arbor test facility for evaluation.

SYSTEM TESTED

This dual-catalyst system employs Gould reduction catalysts (model Gem. 67) for control of oxides of nitrogen and Englehard oxidation catalysts (model 2B) for control of hydrocarbon and carbon monoxide. The reduction catalysts are located forward of the oxidation catalysts in the exhaust system. To facilitate quick attainment of system operating temperature and good cold start emission control, two techniques are employed. First, the distributor timing is modulated for cold start. During starting normal ignition timing for the engine is set. Immediately upon engine startup the timing is retarded and employed for about two minutes before switching back to the normal ignition setting. To allow this timing modulation a dual point distributor system is used in conjunction with manual switching. While manual switching was employed in the prototype vehicle, production vehicles would utilize an automatic timed solenoid. The second technique involves start-up modulation of injection air. During the first two minutes of operation following cold start air is injected at the exhaust ports in front of the reduction catalysts. This injection leads to oxidation both in the exhaust manifold and in the reduction catalyst. After two minutes the exhaust port air is shut off and only normal air injection in front of the oxidation catalyst is employed. Again, on the developmental system air switching is accomplished manually but in production this manual function would also be replaced with an automatic timed solenoid.

The system as tested employed conventional carburetion calibrated to give a relatively constant carbon monoxide level of between 2 and 3 percent. Lean excursions of the carburetor have been minimized through careful bench calibration. Since proper system performance depends on operation within this carbon monoxide band, frequent calibration based on barometric pressure (air density) is required. (One planned test at the EPA was canceled due to excessively low barometer.) In production this sensitivity could be alleviated through the use of barometric pressure compensated carburetion techniques.

The vehicle used for this system demonstration was a 1972 American Motors Matador equipped with a 304 CID eight cylinder engine and an automatic transmission. The vehicle was tested at a 3500 pound inertia weight.

MILEAGE ACCUMULATION AND VEHICLE MAINTENANCE

The dual catalyst system was operated by New York State personnel for 25,000 miles over a period of about 5½ months in both city-suburban and highway situations. It is not possible to assess the equivalency of this accumulation procedure with the current certification driving schedule. Lead-free Amoco premium gasoline (as marketed in the eastern United States) was used exclusively for this mileage accumulation. New York State personnel reported that mileage accumulation will continue.

In general, maintenance on the vehicle followed that recommended by American Motors for its 1972 automobiles and did not specifically follow current certification procedures. As previously noted carburetor adjustments were frequently made to facilitate emission testing under varying barometric conditions.

TEST PROGRAM

All testing was performed in accordance with the 1975 Federal emission test procedure as specified in the November 15, 1972, Federal Register (and appropriate subsequent modifications). Testing and vehicle operation required the use of unleaded gasoline.

A total of five emission tests were run at the EPA laboratory in Ann Arbor, Michigan. The first was conducted in June of 1973 when the catalytic system was at low mileage. Early in November of 1973 the vehicle was tested twice after approximately 25,000 miles had been accumulated on the system. During that testing starting problems attributed to poor choke and inadequate driver operation were encountered. The vehicle was returned in mid-November after a comprehensive tuneup for retest. Two additional tests were run at that time. The first of these latter two tests was voided by a CVS operation error.

Fuel economy for the second and third series of tests has been calculated using the carbon balance technique. For comparative purposes the 1972 Federal emission test procedure has also been used to calculate fuel economy.

TEST RESULTS

Table I illustrates the 1975 composite emission results obtained during the EPA testing. Also presented are fuel economy data calculated using the 1972 Federal emission test results and the carbon balance technique.

During tests No. 2 and No. 3 the vehicle stalled or false started several times during the cold start. This poor performance stemmed from inadequate choking and driver operation and led to relatively high hydrocarbon emissions.

Test No. 4 after tuneup was characterized by good starting performance. This test demonstrated emission levels near the 1976 statutory limits.

CONCLUSIONS

1. At low system mileage the New York State dual-catalyst vehicle met the 1976 statutory levels.
2. Excluding tests which were characterized by cold starting problems, after 25,000 miles the dual-catalyst system is still operating near the 1976 statutory levels.
3. Fuel economy measured was 11% poorer than for a comparable 1973 AMC vehicle but only 3% poorer than for a comparable 1974 AMC vehicle. The test vehicle was a converted 1972 AMC vehicle, but no fuel economy data for a comparable unmodified 1972 AMC vehicle is available.

TECHNICAL ASSESSMENT

The New York State dual-catalyst system closely parallels the type of systems reported by Gould and other manufacturers at the EPA hearings early this year. There are no significant technological differences employed by New York State except that the Gould catalyst utilized by New York State does *not* represent the latest generation of Gould catalysts. The vehicle did display good emission control for 25,000 miles of system operation as contrasted to the unfavorable evaluations reported earlier to EPA by manufacturers.

After meeting with New York State personnel and analyzing the data presented in this report, the EPA technical staff still considers their previous assessment of the dual-catalyst approach as valid. Relatively tight control of air-fuel ratio is required mandating the use of advanced carburetion with air density compensation. The latest test data as reported here indicates that after 25,000 miles of operation the NO_x control has deteriorated and is near the statutory limit. Previous information available concerning the Gould system would suggest that rapid deterioration of NO_x control after 25,000 miles would also be expected to occur for the New York State system. New York State personnel plan to continue mileage accumulation and subsequent data would be useful for verifying the deterioration rate.

While the successful demonstration of 25,000 miles of emission control at the 1976 statutory standards indicates the importance and potential of continuing research and development of the dual-catalyst approach, a single successful test does not indicate that the dual-catalyst approach is ready for implementation on new vehicle production. In his July 30, 1973, decision the Administrator concluded that ". . . although the Gould catalyst has shown by far the best durability results of any (reduction) catalyst to date, more work on matching the catalyst to the engine and on improved fuel metering, accompanied by extensive durability testing, will be required before it will be ready for widespread vehicle use." The data obtained through the testing of the New York State vehicle does not materially change the data base from which the Administrator drew his July 30 conclusion.

TABLE I.—NEW YORK STATE CAR, ANN ARBOR EPA TESTING

Date	Test No.	Odometer mileage	1975 FTP HC	1975 FTP CO	1975 FTP CO_2	1975 FTP NO_x	1972 FTP M.P.G
June 6, 1973	1	28,039	0.33	2.99		0.11	
November 1, 1973	2	49,035	1.02	3.37	746.5	.40	11.2
November 2, 1973	3	49,048	.68	3.22	731.3	.32	11.4
November 23, 1973	4	49,175	.37	1.67	751.4	.47	11.2
1976 statutory standards			.41	3.4		.40	
Average 3,500 lb 1973 vehicle							13.9
1973 AMC 3,500 lb 304 CID (1 vehicle)							12.6
1974 AMC 3,500 lb 304 CID (2 vehicles)							11.6

A SECOND EVALUATION OF THE QUESTOR EMISSION CONTROL SYSTEM—NOVEMBER 1972

(Thomas C. Austin, Test and Evaluation Branch, Division of Emission Control Technology, Environmental Protection Agency)

BACKGROUND

EPA recently performed a short evaluation of a vehicle prepared by Questor Automotive Products of Toledo, Ohio. The vehicle equipped with the Questor "Reverter" emission control system had been available only long enough for one 1975 Federal Test Procedure to be run. Because of the impressive emission levels recorded during the first EPA test (below 1976 requirements) a decision was made to perform a more extensive evaluation at a later date.

Approximately 4,000 miles had been accumulated on the Questor vehicle since the first test. Total system mileage was approximately 8,000 at the beginning of this test series. Questor representatives claimed that all of the mileage had been accumulated using highly leaded fuels. A lead determination, performed by EPA, on a sample of fuel from the vehicle's tank indicated a lead content of 2.5 grams per gallon.

VEHICLE TESTED

The Questor "Reverter" emission control system was installed on a 1971 Pontiac Catalina equipped with a 400 CID V–8 engine, automatic transmission and air conditioning. The heart of the system is a pair of non-noble reduction catalysts sandwiched between partial thermal reactors. Carburetor calibration and exhaust port air injection rates are set such that a reducing atmosphere is still present after the exhaust gas passes through the first partial thermal reactor stage. After the exhaust gas passes through the NO_x catalyst, additional air is added to complete combustion of the HC and CO remaining. Exhaust gas recirculation (EGR) is not used.

One "reverter" is used on each bank of a V–8 engine. Figure 1 is an illustration of a reverter attached to a cylinder head. "Limited oxidation" and "final oxidation" takes place in the partial thermal reactors. The "reduction zone" houses the expanded metal NO_x catalyst. Figure 2 shows a cut-away reverter system installed on a cylinder head. As can be seen from the picture, the construction is double walled to reduce heat loss.

The vehicle's exhaust system is constructed of double walled pipe. Air pump discharge is routed to the rear of the vehicle and pumped into the annular cavity surrounding the inner exhaust pipe. The air is then heated by the hot inner pipe as it is pumped toward the front of the vehicle where it is removed from the annular cavity and injected into the partial thermal reactors at 800° F.

Incorporated in the Questor vehicle is a sub-system to improve fuel economy and reduce system temperatures during high load operation. This system, designated "Normal Operating Temperature Control (N.O.T.C.)" senses both load and time. When the vehicle is exposed to a high enough load for a long enough period of time a portion of the air pump discharge is diverted to the intake manifold, causing enleanment of the mixture. The system is activated when two separate chambers are pressurized by a portion of the air pump discharge. The time required to pressurize the chambers depends on the air pump speed (a function of vehicle speed) and the exhaust backpressure (a function of vehicle load). Normally at loads below those required for a 50 mph cruise the system will never activate because the air pump discharge cannot overcome the built in leakage in the chambers. Above 50 mph the system will only activate if the driver maintains a steady throttle position and does not use his brakes. Brake application causes one of the volumes to dump immediately.

As adjusted on this vehicle the N.O.T.C. system would only be activated during expressway or highway operation in light traffic. Activation causes a considerable loss in NO_x control but good HC and CO control is maintained. Our previous testing of the Questor vehicle indicated that fuel economy of better than 15 miles per gallon could be achieved at 60 mph cruise with the system activated. Properly calibrated the system would not be activated in heavy traffic situations or stop and go driving. As installed on the vehicle tested, the N.O.T.C. system was fully adjustable. A production version would use fixed orifices rather than adjustable valves. The system was never activated during the LA–4 driving cycle of the Federal Test Procedure.

TEST PROGRAM

The Questor vehicle was tested using the 1975 Federal Test Procedure with two different vehicle weights simulated. Two tests were run at a 5,000 pound test weight, the "correct" test weight for the full size Pontiac and two tests were run at a reduced weight of 3,000 pounds simulating a compact vehicle. A description of the Federal Test Procedures is enclosed (Attachment I).

In addition to the gaseous emission tests, the vehicle was also tested for particulate emissions. The particulate testing was done by Dow Chemical of Midland, Michigan through in existing EPA contract. The Dow procedure simulates an air quench of the vehicle's exhaust gas by routing the exhaust into a 15⅞ inch diameter tube where it is diluted to a 500 cfm flow. Twenty-seven feet downstream of the tailpipe samples are pulled from the diluted exhaust through fiberglass filters, millepore filters and an Anderson impactor. Only the particulates still in suspension are captured. While the Dow procedure is not necessarily going to end up as a Federal Procedure, it does allow us to compare particulate emission levels from different vehicles using a common procedure.

TEST RESULTS

Results are summarized in Tables I and II. Table I lists gaseous emission test results using the 1975 Federal Test Procedure for test weights of both 5,000 and 3,000 pounds. Emissions were under the 1976 levels during each test. Hydrocarbon control was very good. During the only test above .03 grams per mile HC (16–0023) the vehicle did not restart well after the ten minute soak. NO_x control was quite good. A 40% reduction in test weight from 5,000 pounds to 3,000 pounds caused a 36% reduction in NO_x levels. CO levels were much lower than normally expected from vehicles using thermal reactors to control CO.

Fuel economy at 5,000 pounds test weight averaged 6.93 miles per gallon. This represents a 20% penalty compared to the average of all 1975 certification prototypes tested by EPA during the spring and summer of 1972. (Corrections were made for the slight difference in test procedure.) The fuel economy improvement measured when the test weight was lowered to 3,000 pounds was not very large because the carburetion, engine size, and driveline were poorly matched for a lighter weight application.

Results of the particulate testing are listed in Table II. At 60 mph steady state the particulate levels were comparable to a vehicle using 0.5 grams per gallon lead fuel. An EPA lead determination run on the gasoline used during the Questor testing indicated a lead level of 2.87 grams per gallon. A conventional (1970 production Chevrolet) run with 3.0 grams fuel emitted particulate levels over four times greater than the Questor vehicle. More data points will be required to lend significance to the results.

CONCLUSIONS

1. The Questor emission control system can achieve the 1976 Federal emission levels at low mileage. Durability is yet to be demonstrated.
2. The Questor system causes a considerable (25%) loss in fuel economy in stop and go driving. There appears to be, however, potential for reducing this penalty by modulating air injection as a function of engine load which would allow leaner calibration.
3. Particulate emission levels from the Questor system appear to be lower than those from conventional systems using leaded fuels. Further testing will be required to verify the preliminary results.

TABLE I.—QUESTOR EMISSION CONTROL SYSTEM, 1975 FEDERAL TEST PROCEDURE

[Emission data in grams per mile]

Test No	HC	CO	NO_x	M.p.g.
5,000-lb test weight:				
16–0023	0.23	2.55	0.34	6.89
16–0033	.01	1.98	.31	6.96
Average	.12	2.27	.33	6.93
3,000-lb test weight:				
16–0029	.03	1.66	.22	7.73
16–0034	.02	2.55	.20	7.70
Average	.03	2.11	.21	7.72

TABLE II.—PARTICULATE EMISSIONS

[All data in grams per mile]

Vehicle	Fuel (g.p.g. Pb)	Hot start, 1972 FTP	60 m.p.h. steady state
Questor 101	2.87	0.15	0.025
1971 Chevrolet	.5		.021
1970 Chevrolet	3.0		.110

FIGURE 1

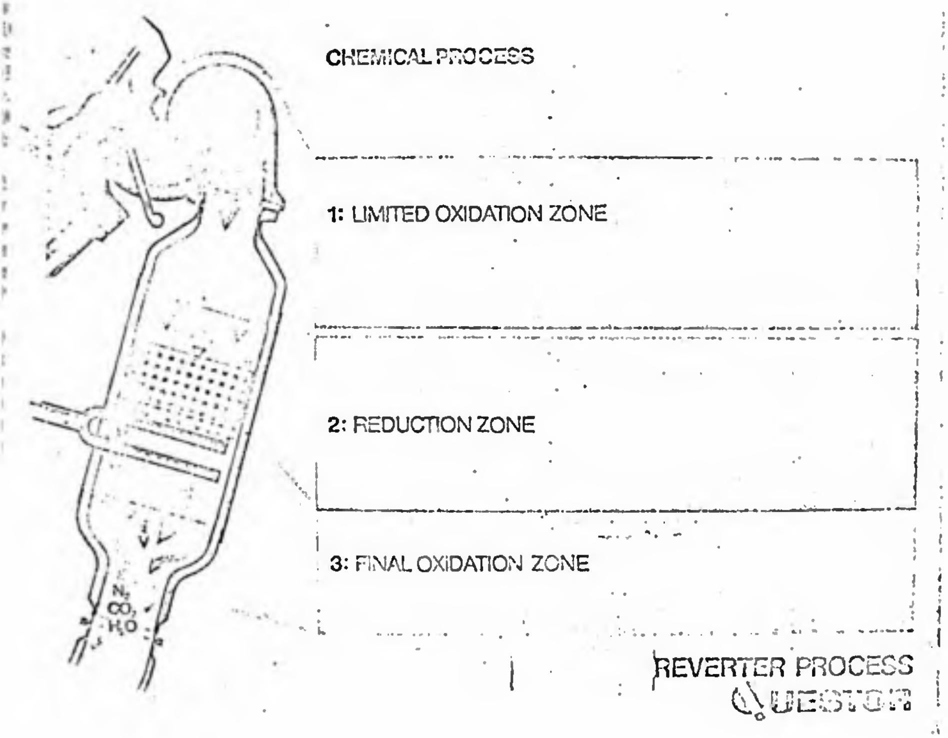
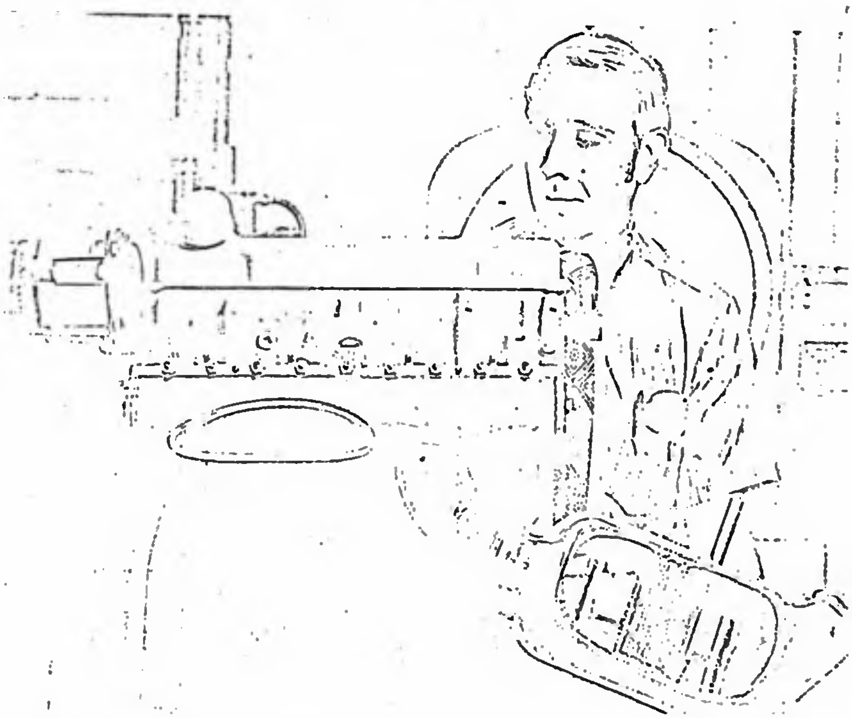

CHEMICAL PROCESS
1: LIMITED OXIDATION ZONE
2: REDUCTION ZONE
3: FINAL OXIDATION ZONE
N_2
CO_2
H_2O
REVERTER PROCESS

FIGURE 2



FEDERAL EMISSION TESTING PROCEDURES FOR LIGHT DUTY VEHICLES

The Federal procedures for emission testing of light duty vehicles involves operating the vehicle on a chassis dynamometer to simulate a 7.5 mile (1972 procedure) or 11.1 mile (1975 procedure) drive through an urban area. The cycle is primarily made up of stop and go driving and includes some operation at speeds up to 57 mph. The average vehicle speed is approximately 20 mph. Both the 1972 and 1975 procedures capture the emissions generated during a "cold start" (12-hour soak @ 68° F to 86° F before start-up). The 1975 procedure also includes a "hot start" after a ten minute shut-down following the first 7.5 miles of driving.

Vehicle exhaust is drawn through a constant volume sampler (CVS) during the test. The CVS dilutes the vehicle's exhaust to a known constant volume with make up air. A continuous sample of the diluted exhaust is pumped into sample bags during the test.

Analysis of the diluted exhaust collected in the sample bags is used to determine the mass of vehicle emissions per mile of operation (grams per mile). A flame ionization detector (FID) is used to measure unburned hydrocarbon (HC) concentrations. Non-dispersive infrared (NDIR) analyzers are used to measure carbon monoxide (CO) and carbon dioxide (CO_2). A chemiluminescence (CL) analyzer is used to determine oxides of nitrogen (NO_x) levels.

These procedures are used for all motor vehicles designed primarily for transportation of property and rated at 6,000 pounds GVW or less, or designed primarily for transportation of persons and having a capacity of twelve persons or

less. Each new light duty vehicle sold in the United States in model years 1973 and 1974 must emit no more than 3.4 gpm HC, .39 gpm CO and 3.0 gpm NO_x when using the 1972 procedure. In 1975 the standards will change to .41 gpm HC, 3.4 gpm CO and 3.1 gpm NO_x using the 1975 procedure. In 1976 the standards will be .41 gpm HC, 3.4 gpm CO and .4 gpm NO_x using the 1975 procedure.

Mr. ROGERS. The second bells have rung. We will recess for 5 minutes. The Chair apologizes.

[Brief recess.]

Mr. SATTERFIELD [presiding]. The subcommittee will come to order.

Mr. Roy.

Mr. ROY. Thank you, Mr. Chairman.

I have just one question, which will probably betray my inability to follow some figures, which I imagine you have presented.

If one barrel of crude oil will produce 50 gallons of leaded gasoline——

Mr. TRAIN. Let us correct that record right now.

Mr. SANSOM. It should be 42 gallons.

Mr. ROY. I had a different figure.

Mr. TRAIN. We are trying to stretch the fuel supply, but I do not think that is probably the way to do it.

Mr. ROY. Let us do it this way, then. If one barrel of crude oil will produce 40 gallons, to use a round figure, of leaded gasoline, how many gallons will it produce of nonleaded gasoline?

Mr. SANSOM. I think that what we are saying is that 1 percent less——

Mr. ROY. It will produce 39.6 gallons of nonleaded gasoline?

Mr. SANSOM. That is right.

Now, that is in 1975. In 1977, you would have that penalty, and in 1980 you would reduce it further, because of these improvements in the refineries.

Mr. ROY. I thank you for your testimony.

That is the only question I have, Mr. Chairman.

Mr. SATTERFIELD. Mr. Nelsen.

Mr. NELSEN. Thank you, Mr. Chairman.

Just a point of information. A number of years ago, our committee had a chance to take a look at the Lear engine. Have there been any new developments on that?

Mr. TRAIN. Mr. Stork will comment on that.

Mr. STORK. Mr. Nelsen, Mr. Lear is one of four system contractors in our alternative automotive power systems program, as well as Thermal Electron, Aerojet General, and Scientific Energy Systems companies.

I am really not in a position to tell you which one will be selected, to take the next step by developing a prototype engine because our technical staff has not advised us of that.

Mr. NELSEN. Thank you very much.

No more questions.

Mr. SATTERFIELD. I have a couple of questions. I want to go back to what we were talking about earlier, the penalty. It seems to me that we are concentrating questions right now on the penalty of converting from regular gasoline to no-lead gasoline.

I want to ask the question of whether or not there are not some other penalties involved with respect to the use of leaded rather than regular gasoline.

Now, I believe your testimony was that 30 percent would be diverted to nonleaded gasoline. Is that correct?

Mr. Train. That would be the upper range, yes.

Mr. Satterfield. And that was predicated before this Mideast shortage which now confronts us?

Mr. Train. Yes.

Mr. Satterfield. Now that we have a lesser supply, would the same number of gallons that constituted the 30 percent you referred to earlier would be converted from the lesser supply now for nonleaded gasoline, or would you reduce that amount?

Mr. Train. I am not sure that I would know how to answer that question. It seems to me that the lower amount of crude available is obviously going to lead to a substantial reduction in the amount of gasoline refined at a lower usage of gasoline. But I would think that proportionally it would remain constant. That, I must say, is an offhand guess.

Mr. Satterfield. Well, I asked that question for two reasons. Let us just confine ourselves to one reason: Whatever the amount that comes out of that barrel will be at the expense of the regular gasoline, will it not? In other words, you are going to have to have that much less regular gasoline for automobiles that run on leaded gasoline. Is that correct?

Mr. Sansom. A very small amount, less than a gallon a barrel.

Mr. Satterfield. Well, if we are going to divert 30 percent, it seems to me that is 30 percent that is not going to be available for automobiles that run on leaded gasoline. Is that right?

Mr. Sansom. The 30 percent is going to be available for the catalyst-equipped vehicles or other vehicles that—you can use unleaded gas in noncatalyst vehicles that can use 91 octane gasoline.

Mr. Satterfield. How many vehicles, what percentage of vehicles do we have today that are going to run on gasoline with no lead at all in it?

Mr. Sansom. I would say half or more. All since 1972 have been built to run on 91 octane gas.

Mr. Rogers. Would the gentleman yield on that?

Mr. Satterfield. Yes; I will yield on that.

Mr. Rogers. I just want to get that clear. I think that is a very important factor. All of the cars since—what date——

Mr. Sansom. 1972.

Mr. Rogers [continuing]. Have been made to operate on 91 octane, which would be the same as unleaded gas.

Mr. Sansom. That is right. General Motors cars in 1971 and subsequent years and other manufacturers' since 1972 and subsequent years can use unleaded gas.

Mr. Rogers. Thank you.

Mr. Satterfield [presiding]. When you are talking about 91 octane. I would like to know which octane you are referring to.

Mr. Sansom. Ninety-one research octane number.

Mr. Satterfield. Well, there are two octane levels, are there not, one the research octane and the other the—I do not know what the exact word for—motor octane?

Mr. Sansom. Motor octane. I was talking research octane.

Mr. SATTERFIELD. I understand that, but I also understand that no low-lead gasoline that that I burn in my automobile today is rated on the gasoline pump at 87 or 89; maybe it is.

Mr. SANSOM. I am sure it is possible to have a lower octane no-lead gasoline. That is right.

Mr. SATTERFIELD. That is not no-lead; that is low-lead.

Mr. SANSOM. Low-lead. But you can buy at the filling station—I will not name the brands—but 91-octane no-lead gasoline.

Mr. SATTERFIELD. Let me ask this question, and I will be through. As I understand it, by adding lead to the gasoline pool you can increase the octane. Is that not correct?

Mr. SANSOM. Yes.

Mr. SATTERFIELD. Are you talking about the penalty when we make no-lead gasoline into 91-octane count out of the pool? Is that not correct?

Mr. SANSOM. Yes.

Mr. SATTERFIELD. Now, you said in the next 2 or 3 years we would be able to produce what I would assume to be additional quantities of low-lead gasoline because you have got more catalytic-equipped automobiles on the road, but there is going to be a lesser penalty.

I would like to know just what it is that we are going to be doing to that barrel of oil to increase the octane if we are not going to use lead for that purpose.

Mr. SANSOM. I think it relates—and, again, this exceeds, certainly, my expertise—as to how the refinery is modified to process a barrel of crude, and there are changes that can be made at the refinery that will reduce the energy penalty associated with putting a barrel of crude through to get some gasoline out at the other end at a given octane number. The model that was used to project these fuel penalties by our contractor assumed that over time more of these investments were made in the refineries.

Mr. SATTERFIELD. Well, it is my hope we are going to have some witnesses——

Mr. HEINZ. Would the gentleman yield?

I would like to——

Mr. SATTERFIELD. I would be glad to yield at that point.

Mr. HEINZ. I would like to inquire of the gentleman from EPA—I understand from your testimony that at the present time—and correct me if I am wrong—you can, given existing refineries and existing levels of lead, refine into gasoline about 50 percent of all the crude oil that goes into a refinery, that is about half of what is produced in existing refineries from existing lead levels can come out as gasoline. Were you, just to take a very clear case, to eliminate starting tomorrow all of the lead in gasoline, would you, under any circumstances, given this same refinery and without respect to the energy penalties at their refinery level, be able to produce 50 percent gasoline from that refinery?

Mr. SANSOM. I think you would be able to produce the same amount of gasoline. You would just have to put other barrels in to supply the energy to the refinery to produce it at the given octane level.

Mr. HEINZ. You would have to, in effect, run the——

Mr. SANSOM. So, in effect, the percentage would go down.

Mr. HEINZ [continuing]. Run the lower fractions through the cracking towers a second time to, in effect, crack it a second time. So you could still get the gasoline, but you would have to apply more energy to the refinery. So the gasoline is there, the octane is there, if you want to get it out.

And the question we are trying to get at is—now, I suppose this is a hypothetical question—given an existing refinery, what would be the energy penalty to go from existing lead levels to the no-lead levels at the same octane rating?

How much more energy would you have to put into that refinery to get that 50 percent gasoline yield? Have you got a number that we could understand between 0 and 100 percent?

Mr. SANSOM. As I understand the situation, it takes about 4 percent of a barrel to put it through the refinery now, leaded. And given the numbers that we have been using here, that you would add in 1975 about a percent to that, which would diminish over time as these other changes in the refinery are made, I think we may, if it is acceptable——

Mr. HEINZ. I thank the gentleman from Virginia for yielding.

Perhaps when we hear from the American Petroleum Institute we could inquire further, because it would be helpful to understand what is going on at the refinery level.

I thank you very much.

Mr. SANSOM. If I may suggest that we might submit for the record a letter clarifying this, given the confusion over the number of gallons per barrel.

Mr. SATTERFIELD. We will do so. Without objection, it will be admitted for the record.

[The following letter was received for the record:]

U.S. ENVIRONMENTAL PROTECTION AGENCY,
OFFICE OF THE ADMINISTRATOR,
Washington, D.C., February 27, 1974.

Hon. PAUL ROGERS,
Chairman, Subcommittee on Public Health and Environment, House of Representatives, Washington, D.C.

DEAR MR. CHAIRMAN: During EPA's recent testimony on automotive emission controls considerable confusion existed on the fuel penalty associated with the introduction of low lead and no lead gasoline. This letter is intended to clarify the matter which appears on pages 19 and 20 of the official transcript.

First, a figure of 350 million gallons of gasoline was stated as the Nation's daily consumption. A more accurate figure would be one on a yearly basis. This would be roughly 100 billion gallons. The figure is arrived at by assuming that on a yearly average basis 7 million barrels of oil per day is used in making gasoline. This figure is then multiplied again by 365 days.

Second, confusion exists over a 30% figure which Mr. Satterfield felt was the gasoline penalty associated with the introduction of low lead gasoline. The 30% number is in fact the amount of low lead gasoline which will be available for consumption in 1975. We do not believe there will be an energy penalty associated with the delivery of this amount of low lead gasoline.

Third, with respect to the crude penalty for no lead gasoline we estimate that it will be in the order of 1.39 billion gallons per year or slightly over one percent of total consumption. On an average daily basis this translates into 3.8 million gallons.

I trust this information will be helpful to the Subcommittee. If I can be of further assistance please let me know.

Sincerely yours,

HUGH MILLER, *Legislative Specialist.*

Mr. SATTERFIELD. And I might inform the gentleman from Pennsylvania that the American Petroleum Institute will testify this afternoon.

Mr. HEINZ. I thank the gentleman.

Mr. SATTERFIELD. Are there any other members of the committee that have a question?

Mr. Preyer.

Mr. PREYER. I have one question for purposes of clarification. Mr. Train, in speaking of the fuel penalty for the 1973 model year, you say it is 10 percent on a sales-weighted basis, compared with noncontrolled cars.

What is a sales-weighted basis?

Mr. TRAIN. That means taking into account the different weights of the vehicles sold. And, as I pointed out, the larger cars sold have a larger penalty which, although I do not think I gave the figure, may go up to something like 18 percent, down to a 2 or 3 percent positive gain at the smaller end of the weight spectrum. And the average we have arrived at simply by taking all of the different models at their respective weights and averaging them out.

Mr. PREYER. Thank you very much.

Mr. CARTER. Mr. Chairman, if the gentleman would yield on that.

Mr. PREYER. Yes, sir.

Mr. CARTER. Do you mean that for the same model care, 1971, for instance, and a 1973, there would be an increased usage of gasoline on the 1973 model by approximately 10 percent?

Is that correct?

Mr. TRAIN. Over the uncontrolled——

Mr. SANSOM. Can we put up the chart that is behind the easel there?

Mr. CARTER. For the same weight car, a 10-percent increase?

Mr. SANSOM. This is comparing a precontrolled car, and since we did not test that many in 1967, we took all of the cars that we tested in 1957 to 1967 as representative of the uncontrolled cars, to the same weight car tested in 1973.

And you can see, as Mr. Train indicated, that, compared to the precontrolled cars, you have a gain in fuel economy, a very slight gain, for the cars that weigh less than 3,700 pounds, and a very large penalty for those that weigh more than 3,700 pounds, on the order of up to 18 percent.

Mr. CARTER. Well, I happen to have a car, one which I bought in 1971, one in 1973, of the same model, and I will assure you that the penalty is much greater than 10 percent.

Mr. TRAIN. It may be a difference in the weight of the vehicles, too.

Mr. CARTER. Well, that is possible. But they are the same model car, the same type car.

Mr. SANSOM. We have information in our fuel economy report that should be available to the committee. We have plotted the changes in vehicle weight of several models over time, and they have increased 100, 200 pounds a year, some of them up to 800 pounds over the last 5 years.

Mr. CARTER. I see. Well, that might be the explanation, but——

Mr. HEINZ. Would the gentleman from Tennessee yield to a question regarding that charge?

Mr. CARTER. The gentleman from Kentucky will yield.

Mr. HEINZ. Kentucky, excuse me. I recognize the tremendous mistake I just made to the gentleman from Kentucky.

Mr. SANSOM. There is nothing wrong with Tennessee.

Mr. HEINZ. I note on the chart that there is a very steep, sudden, and more or less unaccounted drop off between the fuel economy for a car in the 3,500-pound weight class versus one in the 4,000-pound weight class. And it seems to me that is a drop in the neighborhood of 17 or 18 percentage points just over that 500-pound range, and it seems peculiar.

Is there any comment you would care to make as to why there is that rather substantial discontinuity?

Mr. TRAIN. Mr. Heinz, may I say I have been asking the same question. Perhaps we can both be enlightened.

Mr. HEINZ. Is that the point at which everybody switches on their air-conditioners?

Mr. SANSOM. Now, I think that that is a useful analogy. It is kind of like the catalyst. You either have got to have it or you do not have it. And the NO_x levels from small cars are low enough to meet the standard, so you do not have to make the exhaust gas recirculation changes to those light cars. But evidently the way the exhaust gas recirculation system works, if you put it on, then you suffer the implications of it. It is not a continuum; it is a piece of technology.

Mr. HEINZ. You either put it on or you do not. So what you are saying is that, actually, small cars are a good deal two ways. First of all, they use less gas second of all, they are probably, per pound, cheaper than big cars, because they do not have the sophisticated technology that is put on them. I suppose that is a pretty good selling point for any of the automobile people out there today.

Thank you very much.

Mr. TRAIN. The trouble is, you cannot get one.

Mr. HASTINGS. Mr. Chairman?

Mr. SATTERFIELD. Mr. Hastings.

Mr. HASTINGS. Just briefly, is there any catalyst that is known to a manufacturer today that can be put on an existing car, 1973, 1974 model, for example?

Mr. TRAIN. Yes. There are several retrofit catalysts.

Mr. HASTINGS. Then, could you tell me what other modifications are going to be made in the engines when we get into the converters?

Mr. SANSOM. I think we will let Mr. Stork answer that.

Mr. STORK. I think what you may be driving at, sir, is whether the fuel economy gain is attributable to the catalyst per se and whether you can improve fuel economy on an existing car by putting on a catalyst.

Mr. HASTINGS. Or a portion thereof.

Mr. STORK. Or a portion thereof. That would really not be the case. The reason that automobiles, new automobiles, 1975 cars equipped with catalysts will be able to have better fuel economy is simply that the exhaust from the engines themselves can be somewhat dirtier than it is today and it gets cleaned up in the catalyst. The manufacturers, most importantly, will be able to advance spark over where spark is now, change the spark advance curves, get more power out of the car, make it run better, get more energy out of the fuel, and burn up the emissions in the catalyst.

Other changes that are being made on 1975 cars primarily are being made to most emission standards but that motorists will benefit in terms of fuel economy are things like quick heat intake manifold, a fast choke, all of which makes better use of the fuel and makes the car—allows the car to meet emission standards.

Mr. HASTINGS. So, then, there are no modifications along these lines that can be made, for example, to Dr. Carter's 1973 car or my car, that would accomplish the fuel economy by the addition of a retro-fitted catalytic converter?

Mr. STORK. Not economically.

Mr. HASTINGS. That would not be possible?

Mr. STORK. I would not say, sir, it is not possible, but it is not economically possible. You would be a lot better off buying a new car.

Mr. HASTINGS. My point is, I guess, the American public is, believe me, letting us know—and I am sure they are letting you know—about their dissatisfaction with the present mileage, and I would not want them to have an understanding that, even if we do relax the standards for 1975, that we are going to solve the problems for the current car owners.

Along the same lines, what about 1976, 1977 cars, modifications?

Mr. SANSOM. You mean the fuel economy?

Mr. HASTINGS. Are you going to be able to achieve the statutory standards with just catalytic converters going to the years 1976 and 1977 without, unfortunately, I think, perhaps some of the modification that you are going to be able to accomplish in 1975?

Mr. SANSOM. I think—back to the first chart we put up there—that fundamentally what will happen as you go from the Federal interim or California interim standards to the statutory hydrocarbon and carbon monoxide standards, is that they will use some of the devices that they have been using on the 1973 cars.

Mr. HASTINGS. Some of the charts I have seen show even a more drastic loss of economy than you show in yours by 1977 by reimposing some of the modifications that we are going to be able to get rid of in the short term while you go to the catalytic converter; but then, in order to meet those other standards in 1977, you are going to have to put them back on.

And we show in some charts provided by some of the automobile people as much as a 30-percent penalty in fuel economy, and that disturbs me.

Mr. SANSOM. Is this related to the NO_x of 0.4?

Mr. HASTINGS. Well, basically, the hydrocarbons and carbon monoxides, but the chart I have shows, by 1975 standards, roughly the 12-percent economy that you are talking of, but there is a sharp breakdown after that to the year 1977 with those standards; it shows a minus 30-percent deterioration of fuel economy.

Mr. SANSOM. That is with a 0.4 NO_x?

Mr. HASTINGS. That is with 1977—yes, 0.4. That is right.

Mr. TRAIN. Well, as I think the committee knows, we at EPA have suggested a modification in the statutory to 2.0 starting in 1976——

Mr. HASTINGS. That would be a permanent statutory standard?

Mr. TRAIN. From 1976 until 1982, and then go to 1.0. I think the point—by the way, Mr. Hastings, if you do have an analysis, we would be very glad to examine it and comment on it.

Mr. HASTINGS. I would not be surprised if you have seen this one already. I am sure these people have testified in front of you, but I would be delighted to make sure you do get a copy of this.

This was Ford Motor Co.'s testimony in front of the Senate Public Works Committee, and that is one of the things that is somewhat confusing to us, of course. We are getting all kinds of figures, and I am sure you are. We are trying to determine just exactly—we laymen—and certainly I am—which is the present——

Mr. SANSOM. I think that is a very good point. And we have found that a year ago, if you had asked them what was the fuel penalty associated with the catalyst, it was something like 25 percent. This is one of the reasons why I think we feel that we ought to have more test results out of catalyst cars before any change is made in the standards.

We are now testing catalytic cars in our lab at Ann Arbor today, and we will have a much better feel in the spring as to what these cars do. We will not have all the answers, but we will know more.

Mr. HASTINGS. I agree that probably should be done. I am a little bit concerned about putting this off until spring, that we are not going to be in the Congress entirely fair to all segments of the industry because who knows, in the next year we may decide to go to just 1974 standards.

I understand that the leadtime that is necessary for 1975 cars is right now. I do not think they have got the time that you are talking about for certification tests next fall. So I would only hope that we take a very careful look and not then, in 1974, do something that is too late for manufacturers themselves to meet by the time they manufacture 1975 cars. I think it is a serious problem.

Thank you very much, Mr. Chairman.

Mr. SATTERFIELD. Thank you.

Any other questions?

Mr. HEINZ. Mr. Chairman?

Mr. SATTERFIELD. Mr. Heinz.

Mr. HEINZ. One brief question. Back in 1971, I think most cars ran on 94 octane gasoline. Cars were tuned in such a way that you could not really run them on anything lower. Today, as you pointed out earlier in your testimony, cars all have to be able to run on 91 octane gasoline, and as I understand refinery economics, it is easier and cheaper to produce 91 octane gasoline than it is 94 octane gasoline.

If that is correct, I think we ought to get on the record the fact that, as we move down in octane requirements, there is a saving in the refinery which, so far in the discussion today, we seem to have overlooked.

Is that accurate? Are my stipulations essentially accurate?

Mr. SANSOM. I think—my understanding is that that is correct, but that the advocates of using lead in gasoline would hasten to point out that higher compression ratios allow the car to consume less energy to do a given task, and therefore there would be an offsetting effect on the other end.

Mr. HEINZ. Thank you.

I guess I should, so there is no misunderstanding on the record, say that it is not a question of whether we have, in effect, experienced an overall fuel savings by doing this. I am not trying to indicate that at all. Just a question of whether it is easier to produce 91 octane from a refinery without the benefit of lead than 94.

I thank you very much.

Mr. SATTERFIELD. Any other questions of the subcommittee.

Congressman Harvey, a very valued member of the full committee, has been sitting in on these hearings, and I wonder—do you have any questions?

Mr. HARVEY. No, thank you, Mr. Chairman. I am just an interested observer.

Mr. SATTERFIELD. Well, then, if not, gentlemen, we thank you very much for your appearance here today and your testimony. I am sure it will be helpful to this committee in its deliberations.

Mr. TRAIN. Thank you, Mr. Satterfield.

Mr. SATTERFIELD. Our next witness is Mr. Peter N. Gammelgard, American Petroleum Institute.

Mr. Gammelgard, I wish to welcome you to the committee and I wonder if, for the record, you could identify the gentlemen who accompany you this afternoon.

STATEMENT OF PETER N. GAMMELGARD, SENIOR VICE PRESIDENT, PUBLIC AND ENVIRONMENTAL AFFAIRS, AMERICAN PETROLEUM INSTITUTE; ACCOMPANIED BY DR. W. J. COPPOC, VICE PRESIDENT, TEXACO, INC.; DR. DAYTON H. CLEWELL, SENIOR VICE PRESIDENT OF RESEARCH AND ENGINEERING, MOBIL OIL CO.; AND DONALD P. HEATH, MANAGER, FUELS, ENERGY, AND AVIATION PRODUCTS, CORPORATE PRODUCTS DEPARTMENT, MOBIL OIL CO., ON BEHALF OF API

Mr. GAMMELGARD. Yes, sir.

Mr. Chairman, on my right here is Dr. Dayton H. Clewell, a senior vice president of research and engineering for Mobil Oil Co.; and on my left is Dr. Coppoc, a vice president of Texaco, and they are appearing here on behalf of API, as I am.

I would like, Mr. Chairman, to lead into this with a little extra that is not in the material you have there, if I may.

Mr. SATTERFIELD. Please proceed.

Mr. GAMMELGARD. Mr. Chairman, and gentlemen. I need hardly say that these are not normal times. They are extraordinary times and they call for extraordinary action. I believe you are in the process of marking up an energy emergency bill which gives the President unprecedented peacetime powers over energy.

API somewhat reluctantly supported this bill, but did so because we are convinced that half measures will not cope with the energy crisis resulting from recent Arab action in either curtailing or embargoing crude oil to their various customers. What would have been, just a few months ago when I appeared before this committee in September, manageable oil product shortfall of some 5 percent or so this coming winter has now turned into a very serious situation.

The Government is proposing major changes in refinery product yield patterns to greatly decrease gasoline and increase other products, such as heating oils and residual fuel oil. We are not talking about normal seasonal changes. We are talking about abnormal and major changes in refinery operations.

Our industry can be depended on to respond to the best of its ability. There is no way that all demands for oil can be met this winter. Absolutely no way. There will be shortages, and there will be genuine hardships. And the effect on our economy will be substantial.

Under such circumstances, the Government undoubtedly wants to get as much gasoline, heating oil, jet fuel, and residual fuel oil out of every barrel of crude that we do have available to run through our refineries as is possible.

I will now pick up with my other statement, Mr. Chairman. We support the bill, H.R. 11475, which would extend the 1974 tailpipe emission standards for the following reasons:

One. Automotive tailpipe emission standards have become progressively more stringent since 1968. As far as the automobile is concerned, the air is getting cleaner year by year as older cars are replaced by new ones. And with maybe a 25- or 30-percent reduction in gasoline this first quarter of next year, which is predicted by the White House, it will become quite a bit cleaner because the cars will not be around, driving around, completely aside from the other effects.

Two. In order to meet the 1975 interim standards, which are more stringent than the 1974 standards, most cars will need to be catalyst equipped. The use of catalysts in turn requires unleaded gasoline to prevent catalyst deactivation.

Three. For 1975 cars, therefore, designed to run on 91 research octane unleaded gasoline, going to 91 octane unleaded gasoline was based on quick availability. It is important to note that to provide for the production of 91 octane unleaded gasoline has already required a substantial refinery construction program. The industry will be ready to meet the general availability requirement that EPA set sometime back on unleaded 91 by July 1 of 1974.

Four. Model year 1973–74 cars on the average have suffered a 20-percent decline in fuel economy, as compared to 1967 cars. And this is certainly at variance, I believe, with the previous witnesses. Our figures, based on a very fine technical analysis, indicates about 15 percent of this loss—and this is not 15 percent of 20, or 3 percent, but a 15 out of the 20, a chunk like that—has been caused by emission controls, of which about 7 percent was caused by a drop in compression ratio to an average—I think the average drop was about 1.1 compression ratio numbers. The lower compression ratio enables a car to run on the 91 octane gasoline, leaded or unleaded.

Five. It has been estimated that the use of catalysts will permit 1975 cars to attain a 2- to 3-percent gain in fuel economy. This saving in energy, however, is offset by the fact that about 3 percent less gasoline can be made from the same amount of crude than could be made if 91 octane gasoline were leaded.

Six. If the 1974 emission standards should be continued, then no catalyst would be required, and leaded gasoline could be continued with substantial positive effects on the energy supply situation. The refinery industry will be capable of making 91 octane, no-leaded gasoline by mid-1974. The addition of 2½ grams of lead to each gallon of this gasoline would increase its octane number to about 98 research octane number. This step could be taken quickly.

Seven. The addition of 2½ grams of lead per gallon would permit an increase in fuel efficiency of about 13 percent; since the compression ratio could be increased and the car could still meet the 1974 emission standards, crude savings would be substantial. We estimate 8½ percent.

Eight. Car manufacturers can increase compression ratios rapidly.

Nine. With the use of 2½ grams of lead per gallon most of the 15-percent loss in fuel economy shown by the 1973–74 cars due to emission controls could be regained. Moreover, increasing compression ratios is only one, though a very important factor in regaining fuel economy. Such other factors as improved carborators and high energy ignition systems would contribute toward fuel savings. And it is absolutely misleading to claim that the 1975 catalyst emission cars would have a fuel economy of some 13 percent. In fact, I remember back in September, that happened to be out of the same company, 18 percent.

In summary, freezing the 1974 standards: One, would still provide the country with continuing improvement in air quality; two, it would permit quick steps to be taken by both the oil and auto industry to regain fuel economy; and three, in the longer term, it would permit the development of more efficient engines, such as the stratified charge engine, which in turn would permit by 1978 or so the implementation of more stringent emission standards without further loss in fuel economy.

One additional amendment to the Clean Air Act is absolutely essential, if tailpipe emission standards are to be frozen at the 1974 level. EPA last week promulgated regulations reducing the overall average lead count in gasoline to 1.7 grams per gallon effective January 1, 1975, and lowering this limit incrementally each year thereafter through 1979 to 0.5 grams in the terminal year, and then level from there on out. Implementation of these regulations must be suspended if the petroleum industry is to continue to produce the necessary volume of higher octane gasoline, and to do so without a—and please change that word tremendous, that is an error—significant 130,000 barrel per day increase in crude consumption, and without construction of a large amount of additional refinery reforming capacity.

I would like to take just a minute here on construction capacity of the industry. We have been asked to make a lead free gasoline by 1974, the middle of the year. We are now being asked to reduce the lead in the remainder of the gasoline. We are being asked by the White House to change the gasoline yield patterns in our refineries as soon as possible, very substantially by some 900,000 barrels a day, not gallons, but barrels a day, of less gasoline, and to divert that into heating oils and residual fuel oil and jet fuel.

The amount of construction that will be needed to do some of these, to make some of these changes is very substantial, and I think far exceeds the capacity of the construction industry in the United States. Furthermore, we heard earlier that there is a possibility of sulfate emissions from the SO_2 going over the catalyst and forming sulfuric acid mists, and solid sulphate particulates.

The Environmental Protection Agency made the remark here on the Senate side recently that should this become a problem, they would merely ask the refining industry to desulfurize the gasoline at the refineries, so the sulphur would not be in the fuel to turn into these sulfuric acid mists.

It seems to us that the far greater logic is on the side of do not move on an unknown, unproven system that can introduce a new health hazard, that could put a strain on the construction industry; take the sulfur out before we have a sulfuric acid mist problem in this country, which could not be done if the construction industry is completely loaded.

And I can tell you if the Alaska pipeline starts construction pretty soon, it will drain many of the welders in the United States to put that line together over the next 3 years.

These are problems we must face up to. And this business of just saying, it is two-thirds of 1 percent and there are 50 gallons in a barrel, and how to design a refinery; it kind of makes me—well, I will not say it. I will stop right there, and we will be ready for any questions.

Mr. SATTERFIELD. Thank you very much.

Do you have any questions, Mr. Kyros?

Mr. KYROS. Thank you, Mr. Chairman.

Mr. Gammelgard, you say on page 3 of your statement in summary, "freezing the 1974 standards would still provide the country with continuing improvement in air quality."

Mr. GAMMELGARD. Yes, sir.

Mr. KYROS. Why is it continuing?

Mr. GAMMELGARD. Because you have a reduction in the 1974 automobile model year cars, that a substantially reduced carbon monoxide and hydrocarbons and also somewhat on NO_x, but these are substantial reductions. As these new—each year's crop of new cars comes into the market with substantially reduced emissions, and practically at the other end of the line, pushes out an old crop 10 or 11 years old; this will result in a continuing improvement.

Mr. KYROS. All right.

We say that the production of gasoline without lead additives causes us to build the new kind of refineries that would give us the unleaded gas of a similar octane. Second, this type of gasoline gives us some kind of a crude oil penalty.

Mr. GAMMELGARD. Yes, sir.

Mr. KYROS. Is that correct?

Mr. GAMMELGARD. Yes, sir.

Mr. KYROS. You know that statement is in great dispute in the Senate hearings. I have talked with many people about this and have received many different answers about it.

But are you certain those are the facts, that, indeed, there is a crude oil penalty if you take all of that lead out of gasoline?

Mr. GAMMELGARD. Indeed, there is. If you want to make the same volume and quality of gasoline, there just has to be.

Mr. KYROS. In other words, to achieve, for example, an 89 or 91 research octane level unleaded gasoline, you have to use more raw material and more crude to get it if you are going to refine it to that point?

Mr. GAMMELGARD. That is correct; either use more crude or use the same amount of crude and then suffer a fall-off in other products made from that barrel of crude. The typical yield of gasoline is right at 47 percent gasoline out of a barrel of crude, in the United States in the year 1972.

Mr. KYROS. All right.

Now, it is also part of the problem that some of the oil companies—like maybe Exxon—have gone ahead with the new refineries while others have not; that is the refineries that would provide unleaded octanes of 91 percent?

Mr. GAMMELGARD. I do not think so. To the best of my understanding, the whole industry has moved to comply with the EPA regulation that says that every station selling over 200,000 gallons of gasoline a year will have to have at least one grade of unleaded gasoline come July 1, 1974. And I do not think that the companies are sitting still on that.

Mr. KYROS. All right.

The first point, though, is we ought to freeze the standards of 1974 for at least a year, or so. Is that right?

Mr. GAMMELGARD. Absolutely.

Mr. KYROS. And second, that we ought to put some lead back in gasoline, not to suffer the crude oil or crude raw material penalty?

Mr. GAMMELGARD. That is correct.

Mr. KYROS. Does not that mean that if we do that, we run the risks that have been testified before this committee of continuing to put lead in the atmosphere in some urban areas where cars are concentrated?

Mr. GAMMELGARD. EPA has made a report on lead traps, and the efficiency of lead traps has been studied by their technical people. And if my memory is correct, they said that lead traps can be put on automobile tailpipes, which will capture 65 percent of the lead particulates that hit the trap in the tailpipe.

Now, this would be an immediate reduction in all existing cars if the lead traps are put on all cars nationwide.

Mr. KYROS. Is that something that could be put on in a garage, rather than on a production line?

Mr. GAMMELGARD. Right.

Mr. KYROS. You feel that this oil shortage, particularly in gasoline, since crude oil is going to be diverted to No. 2, and bunker heating fuels for industry, that the gasoline shortfall is going to be much greater than we originally projected, not just 17 percent. It is much higher?

Mr. GAMMELGARD. I would not be at all surprised at 30 percent.

Mr. KYROS. Well, then, would you then say also as a matter of controls, we ought to have rationing of gasoline?

Mr. GAMMELGARD. I do not know, Mr. Kyros, if rationing would be dictated. It probably would strain our credibility, or credulity, I guess it is, to think that the public voluntarily would go along with the 30-percent reduction. It could be tried.

I was on the New York freeway over the Thanksgiving holiday and everybody was doing 50 miles an hour except two cars that were off to the side with police patrol cars giving them tickets for having gone a little faster. I think highway driving decreased. The gasoline demand has tapered off to around a 2.6-percent increase for a recent 4-week period.

This is not enough though. It has to take a real decrease, not just a modest increase. So rationing may be necessary.

Dayton, do you want to add, or do you, Joe, to that thought?

Mr. CLEWELL. Yes; I think it may be necessary. It is going to be a very, very complicated thing to administer, and it would take an awful lot of bureaucracy, that will have to be set up to do it. I think we ought to try everything we can before we really have to go to rationing.

Mr. KYROS. I know there are other members that would like to ask questions, but it is very interesting. Thank you very much.

Thank you, Mr. Chairman.

Mr. ROGERS. Mr. Carter?

Mr. CARTER. Thank you, Mr. Chairman.

I have heard it variously estimated that our country uses 17 million barrels of crude oil a day, and up to 20 million. What is the correct figure?

Mr. GAMMELGARD. I think the correct figure, our total demand, is around 17½ million barrels a day of liquid oil products, products not crude oil. Now, our refineries are capable of running, I think, about 13½ million barrels a day of crude oil and some other raw materials from the oil fields. We do import roughly 3 million—or had been importing, let me put it that way, until recently, 3 million barrels a day of products, and 3 million barrels a day of crude oil.

So our domestic production of crude oil, plus the imported crude oil, filled our refinery needs. We are not now able to get all of the crude, due to the Arab-Israeli situation, that we would like to have, nor can we import all of the products that we would like to import, because the Arab countries, as you probably realize, have told anybody that is getting their crude oil that they should not ship products from that oil to the United States or to Holland.

Mr. CARTER. Yes, sir.

Mr. COPPOC. May I add a—it is necessary that you look at those numbers in a time frame. For example, that 17.5 million barrels a day that Nick just mentioned for 1973 averaged 16.2 million barrels a day in 1972. The increase in consumption has been that rapid. You go back 10 years and the number was something like 10 million barrels per day, which illustrates a big part of the problem, you see.

Mr. CARTER. What is our production in the United States today of crude?

Mr. COPPOC. 9.2 million barrels a day.

Mr. CLEWELL. About 10.

Mr. COPPOC. My figure does not include what are called "natural gas liquids."

Mr. GAMMELGARD. And that is somewhat over a million barrels a day, and that plus the 3 million barrels a day of imports just about filled our refinery requirements at about 13½ million.

Mr. CARTER. We have got 1 million from Canada. Is that correct?

Mr. GAMMELGARD. A little over 1 million from Canada, and about 350,000 a day from Venezuela.

Mr. CARTER. I thought it was about 2—only 350,000 from Venezuela.

Mr. GAMMELGARD. I think that is correct from Venezuela.

Mr. CLEWELL. I think it is more than that.

Mr. CARTER. 2 million?

Mr. CLEWELL. No; but Venezuela is our second largest source of imports of crude oil and products.

Mr. CARTER. Yes, sir.

And of this, of the crude oil that you manufacture, or that you have, we use 13½ million barrels. You have the refining capacity for that at the present time?

Mr. GAMMELGARD. Yes, sir, in the United States.

Mr. CARTER. To refine that much each day?

Mr. GAMMELGARD. Yes, sir.

Mr. CARTER. If we convert this into leaded gasoline, we would get a benefit. Is that correct?

Mr. GAMMELGARD. Yes, sir.

Mr. CLEWELL. Compared to unleaded.

Mr. GAMMELGARD. Certainly.

Mr. CARTER. And you have got a 2 to 3 percent—no a 3-percent penalty for conversions to 91 octane gasoline. Right?

Mr. GAMMELGARD. Yes.

Mr. CARTER. And a 2- to 3-percent gain in fuel economy by adding lead. Is that correct?

Mr. CLEWELL. Well, it depends on——

Mr. GAMMELGARD. Fuel economy gain in the automobile engine?

Mr. CARTER. Yes, sir.

Mr. CLEWELL. Well, the lead itself does not give you any increase, but by adding lead——

Mr. CARTER. It increases the octane.

Mr. CLEWELL. That is right: by increasing the octance, you can increase the compression ratio of the engine and get more efficiency that way.

Mr. CARTER. 2.5 grams of lead, I suppose, per——

Mr. COPPOC. Gallon.

Mr. CARTER. Gallon. All right, sir.

Thank you, Mr. Chairman.

Mr. ROGERS. Mr. Heinz?

Mr. HEINZ. Thank you, Mr. Chairman and Mr. Gammelgard and your associates. I just want to take this opportunity to say that the petroleum industry over the years has an excellent record of meeting the needs of the American consumer. And based on information that has come to me, you have gone out of your way to accommodate the changes that public health and other requirements have necessitated. And you are to be sincerely commended on your response to your public responsibility to date. And I mean that sincerely.

Mr. GAMMELGARD. Thank you.

Mr. HEINZ. You discussed in your statement compression ratios, and what is involved in increasing the compression ratio of a car that you have? I have a 1973 car. How can I increase the compression ratio on it to take advantage of the higher octane gasoline that you would make available, were we to permit lead to be used?

What would I have to do to my 1973 car, because the mileage on it, I would like you to know, is not so good?.

Mr. CLEWELL. We can all take a crack at this. But of course now, just to increase the compression ratio, I suppose the simplest thing is to put on a thinner head gasket, so you do not have so much room at the top of the piston as you did before.

Therefore, when the piston comes up, you go to a greater compression.

Mr. HEINZ. A thinner head gasket?

Mr. CLEWELL. Yes; however, this does not really solve all of your problem by any means in terms of getting this efficiency back, because as you increase the power, you should now change some of the gear ratios, say, in the rear axle; perhaps the timing on the spark should be changed. And of course for a lot of old cars, it is not practical anyway to put in this head gasket.

Mr. HEINZ. That sounds very expensive to me, and presumably it is, therefore, in terms of the 1974 model year, which we are considerably well into now; there would be relatively little that Detroit could do. You were talking about—any effect that you were talking about would be on 1975 model year as a practical matter.

Mr. COPPOC. At the earliest.

Mr. CLEWELL. Yes, that is right, at the earliest.

Mr. HEINZ. At the earliest.

Mr. CLEWELL. It is best to do it when they are manufacturing it, rather than afterward.

Mr. HEINZ. I think you made that point abundantly clear. Would you expect that—and I guess we will have automobile manufacturers in to testify later—would you expect that even with respect to the 1975 model year, that those changes could actually be made that you suggest?

Mr. CLEWELL. I think we said in there, probably some of them could. We think it would probably be 1976 before they could really make the changeover to take advantage of the higher octane.

Mr. HEINZ. Two and a half years from now. So that while that is something that might be a good thing to do from fuel economy, the benefit from that is a couple of years away.

Mr. COPPOC. This is correct.

Mr. CLEWELL. There is practically nothing we can do for the 1974 cars.

Mr. HEINZ. All right. You mentioned that the final yield is about 40-percent gasoline. What octane are you assuming, assuming no lead?

Mr. COPPOC. The pool was about 88½ in 1970 without lead. That's just as if you dumped all the gasoline stocks in a great big tank and took a sample, and 88½ would be the octane number.

To raise that to 91 as required in the intervening years an amount of construction just for that purpose alone would be a little more than equivalent to the average amount of construction in the refining and petrochemicals industries over the last 5 years.

Do I make myself clear?

It is about $2 billion.

Mr. HEINZ. A lot.

Mr. COPPOC. To get from 88½ to 91.

Mr. HEINZ. Let me ask you a question a little differently so that I understand what you had to do.

Were you to take the 1970 refinery that produced 47-percent gasoline at an average pool strength at 88½ octane, and you were to program that refinery to produce 91 octane gasoline, what would be your gasoline yield from that refinery?

Would you imagine, would it be 40, 30, 46 percent?

It is going to be less than 47 percent, I would assume.

Mr. COPPOC. May I take the time to you a horrible example?

In one of our small refineries located in the Midwest, in which we were faced with exactly that problem, we increased the total investment in that refinery, by 47 percent. When we had finished we were able to produce about 92 percent as much gasoline as we could before we made, invested the additional 47 percent. This also covered cleaning up the water and some emissions from other units.

And the numbers are—I am speaking from memory, so do not argue whether it is 91 or 93. It is about 92 percent.

Mr. HEINZ. Well, you probably went through, from what had previously been 47 to about 43 percent, roughly.

Mr. COPPOC. I am not positive about the yield.

Mr. HEINZ. After spending a great deal of money to bring that about.

Mr. COPPOC. Now, part of that decrease in yield of gasoline could be made up in the yield of other products that came out of the refinery, so that we were able to produce about 96 percent as much total product.

Now, the cars for which that product was designed to operate, would give the ultimate consumer fewer ton-miles of transportation per gallon of gasoline than would the product we turned out before that conversion.

Mr. HEINZ. Why was that?

Mr. COPPOC. It is because it is 91 octane clear. Part of that time we were using 88½ roughly base clear, and adding lead to it, so that the pool——

Mr. HEINZ. Was 94?

Mr. COPPOC. It was 96, 96½ because of the combination of regular and premium, you see, and that would give you a higher compression ratio with the attendant additional fuel economies.

Mr. HEINZ. Mr. Chairman, I thank you. I might have—I have used up my 5 minutes. If we have more time I might come back.

Mr. ROGERS. Mr. Hudnut?

Mr. HUDNUT. Thank you, Mr. Chairman.

I would like to ask you the same question that I asked Mr. Train. I believe you heard it. It has to do with the correlation between gasoline mileage and the utilization of the auto emission control devices on the current vehicles.

Do you think there is a negative correlation, and that there is a discernible decrease in the amount of miles to the gallon as a result of the use of these devices?

And, if so, would you favor repealing that section of the Clean Air Act that requires manufacturers and dealers not to tamper with or disconnect——

Mr. CLEWELL. If I get the question correctly, you are referring to the statement he made that of the small cars, in recent years, with the application of emission controls, their fuel economy has improved. Is that the question?

Mr. HUDNUT. My question has to do with the observation of, as I said before, the man in the street, that because he has got an auto emission control device on his new car, medium size models and up, that he is getting less miles to the gallon. A lot of people complain to me about this, and say, if they did not have these, if they were disconnected, these devices, they would be getting better mileage. They feel that this is one of the reasons why we have a fuel shortage.

Do you agree with that observation?

If so, would you favor legislation permitting the disconnecting of the devices?

Mr. CLEWELL. I would have to think about that a little bit. I would say this, that I do not think it is true generally that by disconnecting them you are going to have worse fuel economy than you did before.

On the other hand, I do not believe that by disconnecting you are going to regain all of the fuel economy that you lost by the fact that they put them on.

So, I would say on balance, it would probably come out that by disconnecting them you would have some improvement in the fuel economy. Now, this would be primarily, I believe, for the 1973, 1974 cars.

Mr. HUDNUT. I am not talking about the new catalytic converters. I am talking about——

Mr. COPPOC. This means a readjustment of spark timing, mixture strength, and so forth.

Mr. HUDNUT. Compression ratio.

Mr. COPPOC. Well, compression ratio you are pretty well stuck with since 1971, and that is the catalyst's penalty. Compression ratios were lowered in order to provide a market for 91 research octane number gasoline, so we could go into the business of making lead-free gasoline at that octane number and build up a market prior to the introduction of catalyst equipped cars. The introduction of 91 research octane number gasoline and the reduction in compression ratios that took place with the first of the 1971 models was directed toward the use ultimately of a catalyst technology. But now that the compression ratios are down, there is not much you can do to change it.

Mr. CLEWELL. The easiest one would be to disconnect the exhaust gas recirculation, or EGR, as we call it, the system put on to control the NO_x, or oxides of nitrogen. Disconnecting that is a fairly simple thing to do, and it would increase the fuel economy, maybe about 3 percent.

Mr. HUDNUT. If we have a real fuel shortage, do you not think that would be a pretty good idea?

Mr. CLEWELL. I am not going to disobey the law. If you change the law, I will do it.

Mr. HUDNUT. Right, because you do not want a $10,000 fine.

Thank you, Mr. Chairman.

Mr ROGERS. Mr. Satterfield?

Mr. SATTERFIELD. Thank you, Mr. Chairman.

I would like to ask you this question, Mr. Gammelgard. What would it mean in terms of additional inventory for gasoline if the oil industry is able, on July 1974, to have lead-free gasoline for use in catalytic equipped cars?

Do you have a figure for that?

Mr. GAMMELGARD. We made an estimate in the industry several months ago, and making an allowance for the fact that some companies are now three-grade marketers and already have the facilities in, in which case it would just be a matter of switching one of those systems over to unleaded. Taking that into account, the additional inventory is estimated at some roughly 10 million barrels of gasoline, which translates to some 400 million gallons of gasoline. It is a little less than 10 million barrels, the way our people look at it.

To relate that to the total gasoline inventory of the Nation, a typical inventory runs about 200 million barrels, so 10 million is 5 percent of 200 million. And at a time where we may be 30-percent short, to add a 5-percent additional penalty—it is a one-time penalty, but nevertheless it is a penalty—it comes at the worst possible time. It is lost for all practical purposes until you finally flush the system out and gain back that gasoline. It could not come at any worse time.

Mr. SATTERFIELD. Would that mean, then, that an automobile owner with a catalytic device equipped automobile might have difficulty in finding nonleaded gasoline?

Mr. GAMMELGARD. Yes; there is no question about it. I think we are having difficulty finding gasoline now, and we have not seen nothing yet, believe me. I am not trying to be an alarmist—I am just trying to be a realist. Wait until next January or February, when we are trying to turn out all of the heating oil we can, all of the jet fuel, and let gasoline sort of be starved out. And that is the time, toward the end of the first quarter, that we should be building gasoline inventories for the summer peak—and we are not going to be able to do it, period.

Mr. SATTERFIELD. Well, in effect this will mean having two classes of gasoline, is that going to complicate the delivery problem?

Mr. GAMMELGARD. Yes; it will, particularly in a shortage situation. If you have more gasoline than needed, it would not be too much of a problem. You would get some more equipment and that would be it.

Mr. SATTERFIELD. And if we were to suspend the 1975 interim standards, and thus not require catalytic devices on automobiles for 1975 models and beyond, you would not be faced with the problem?

Mr. GAMMELGARD. That is correct.

Mr. COPPOC. Provided EPA changed its present regulation. At the present time there is a very severe penalty for our not having unleaded gasoline available in every station that has, that sells over 200,000 gallons a year.

Mr. SATTERFIELD. I undestand that.

Mr. COPPOC. Something would have to be done about that.

Mr. SATTERFIELD. What is the penalty of that phasedown, incidentally?

Mr. GAMMELGARD. $10,000 per day of occurrence, I think.

Mr. CLEWELL. Per station.

Mr. SATTERFIELD. How many gallons are we talking about that would be involved in that loss?

Is there an appreciable loss in terms of gasoline because of the phasedown?

Mr. COPPOC. With the phasedown that they—you mean the lead phasedown schedule EPA had published?

Mr. SATTERFIELD. Yes.

Mr. COPPOC. Yes; that runs—and this may be where some of the confusion occurred in the EPA testimony, because they have been receiving information on what effect the phasedown has on the availability of gasoline—and under those circumstances this runs initially, by our estimates, in the range of 100,000 to 150,000 barrels per day.

Mr. SATTERFIELD. This is in addition to what we have been talking about?

Mr. COPPOC. Yes; this is the penalty which is due to the phasedown. You calculate it on the basis of how much gasoline you could make if you were able to lead that gasoline to current levels, you see. And then, how much could you make if you could not lead it to current levels in accordance with the phasedown rules. And this, because they spread that average out over all of the gasoline that was sold, means that as the demand for unleaded gasoline goes up, then you have more lead available to put in the leaded gasoline to satisfy the old, higher compression ratio cars. So that the penalty appears to go down a little bit because you do not have to reform and so forth as vigorously for the unleaded—or for the leaded part, the bulk of your fuel.

It is a peculiar thing, but it may account for their rather odd statements about what was going to happen in the refining industry.

Mr. SATTERFIELD. I appreciate that explanation, because I frankly admit I was confused as well.

Mr. COPPOC. I think we all three were.

Mr. GAMMELGARD. API wrote to Mr. Train on November 20 and that is mentioned in the letter, and, I would be pleased to submit it for the record. It is a four-page letter.

Mr. SATTERFIELD. Mr. Chairman, could we receive that in the record?

Mr. ROGERS. Certainly. Without objection, so ordered.

[The letter dated November 20, 1973, referred to, follows:]

AMERICAN PETROLEUM INSTITUTE,
Washington, D.C., November 20, 1973.

Hon. RUSSELL E. TRAIN,
Administrator, Environmental Protection Agency,
Washington, D.C.

DEAR MR. TRAIN: We at the American Petroleum Institute are aware that, pursuant to a court order, you must announce what action EPA intends to take on the reproposed schedule for reductions of lead in leaded grades of gasoline by November 28, 1973. Given both the closeness of the deadline and the sheer volume of relevant data, we are concerned that a few points of paramount importance to the petroleum industry and to the economy of the country as a whole may not be fully appreciated. We would therefore like to summarize these points for your consideration as briefly and as clearly as we can.

1. *We do not believe there is a sound scientific basis for EPA's conclusion that the use of lead in gasoline constitutes a threat to public health.* This position is supported by certain internal EPA documents which have recently been made public, including the memorandum "Public Comments on Proposed Lead Regulations" submitted by Joseph Kivel on July 6, 1973.

The memorandum, which we presume you have seen, consists largely of quotations from papers written by physicians, environmental toxicologists, and other scientists. These independent authorities all cast serious doubt on claims that there is a public health basis for reducing the amount of lead in gasoline. While we recognize that this internal memorandum was a "devil's advocate" paper, consisting entirely of opinions contradicting the EPA viewpoint, we believe those opinions must be given equal weight with those cited in support of the proposed low-lead gasoline regulations in EPA position papers.

2. *Even if at some future date lead in gasoline should prove to be a health hazard, the existing regulation requiring a lead-free grade of gasoline may by itself reduce automotive lead emissions to EPA's target level.* At a December 27, 1972, news conference, former Administrator Ruckelshaus displayed a graph depicting the lead emission reductions expected to result from the application of both the final regulations governing lead-free gasoline and the proposed amendment calling for a phased reduction of lead in leaded grades of gasoline. He also displayed a graph showing the reductions which would result from the application of the regulations *without* the proposed amendments, assuming that 1975 and later model vehicles use only lead-free fuel. (See Attachment 1.)

As can be seen from the composite of these graphs, reductions in automotive lead emissions are expected to be dramatic over the next decade, with or without controls on the lead content of leaded grades. In either event, if EPA's assumptions concerning future vehicles are correct, automotive lead emissions will be at the same negligible level by 1985. The effect of the proposed controls on leaded grades would be to accelerate the emission reduction process slightly and temporarily to achieve about a two-year jump around 1978–1979, a difference which would gradually shrink to zero.

3. *Meeting the lead reduction schedule proposed last January would require the refining of an additional 24–48 million barrels of crude oil annually, depending on the extent to which catalytic and noncatalytic emission controls are used on future automobiles.* The impact in reduced gasoline yield per barrel of crude would be significant—even at the lower figure of 24 million barrels per year—in view of the current shortage of both raw materials and of refinery capacity.

4. *A newer, more stringent lead reduction schedule than that proposed last January would place an even heavier strain on the nation's crude reserves and limited refining capacity.* We understand that the lead reduction schedule proposed in January of this year, reducing the lead content of the *leaded* gasoline pool to 2.0 gm/gal by January 1, 1975, and to 1.25 gm/gal by January 1, 1978, may be replaced—apparently without an opportunity for public comment—by a newer schedule reducing the lead content of the *total* gasoline pool to 1.4 gm/gal and to 0.6 gm/gal by these respective dates.

While it may be argued by some that this schedule will have about the same impact on the refining industry as the original phasedown proposal, the facts do not support this contention. Total gasoline pool averaging does give the refiner greater flexibility, but the impact of any average level on a given refiner depends on the relative volumes of premium, regular and/or lead-free fuel, the more severe the crude penalty will be. In January 1975, the volume of lead-free fuel produced by many refiners is likely to be very small, and the output of higher-octane leaded grades will be only very slightly less than it it today. Thus, for these refiners, the newer schedule would require a much larger decrease in lead use per leaded *gallon* than the schedule proposed in January. Assuming these refiners are able to comply—or are given enough time to comply—the result will be a much more severe penalty in raw materials than that associated with the schedule proposed last January—that is, unquestionably more than the 48 million barrels per year cited in Point 3 above.

5. *The nation cannot afford the additional loss in refining capacity and product yields.* Refinery design and construction firms are already operating at capacity. How well these firms can respond, or whether in fact they can respond, to those refiners faced with the necessity of making much more severe product quality changes than anticipated is not at all clear. We understand that EPA expects that some 12–20 small refiners may be forced to shut down as a result of the lead-free and low-lead gasoline regulations.

We find it difficult to believe that EPA would knowingly contribute to the demise of a segment of industry on the basis of a decision to achieve a slightly accelerated reduction in lead emissions by an arbitrary date. It seems all the more unthinkable that such a decision would be made at a time when the nation so desperately needs more, not less, refining capacity. Assuming, for example, that an aggregate of 100,000 barrels per day in refining capacity might be lost through shutdowns, that would mean *additional* deficit in crude oil refining capacity of more than 36 million barrels per year. To understand the potential overall impact on energy availability, one must add this to the more than 48 million barrels per year in additional crude runs needed to produce low-lead gasolines of conventional octane. This means a potential deficit in capacity of more than 84 million barrels per year in 1975.

6. *Promulgation of a new, more restrictive lead phase-down schedule without an opportunity for comment by affected parties would be an unjust denial of due process.* If, despite the evidence to the contrary, it is determined that a lead phase-down is needed, both the proposed regulation and the supporting documentation should be published in the *Federal Register* for comment before final promulgation.

7. *Acquiescence in the NRDC suit could establish a dangerous precedent.* Under the Clean Air Act, promulgation of control or prohibitions for fuels and fuel additives is entirely within the Administrator's discretion. EPA's apparent decision not to appeal the court order in the NRDC suit would mean abandonment by EPA of a principle that the agency has hitherto guarded with the utmost vigilance—namely, that EPA cannot be sued for failure to perform a purely discretionary act. Such a legal precedent could have serious repercussions not only in the future implementation of the Clean Air Act, but throughout the federal system.

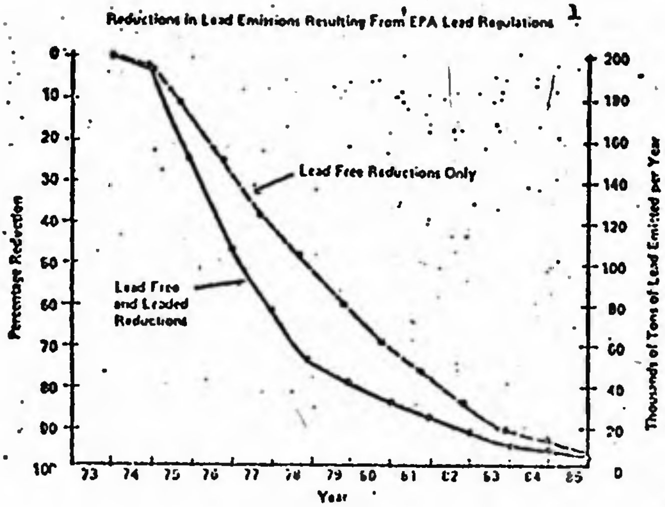
These, briefly, are the major points troubling us. In view of the uncertainties concerning the types of automobile emission control systems that will be used in the future, the severity and duration of the current energy shortage, and the complex array of other problems now facing petroleum refiners, we would appreciate an opportunity to review these matters in greater depth at your earliest convenience.

Sincerely,

NICK GAMMELGARD,
Senior Vice President,
Public and Environmental Affairs.

Attachment.

ATTACHMENT 1



As reproduced in The Oil Daily, January 29, 1973, p.18

Mr. SATTERFIELD. I think you answered that question, but I know Mr. Heinz had earlier asked it of the gentlemen who preceded you, and was given an answer to his question that the more you phase down the octane, the greater savings there is to the refinery. And I think you have answered that question.

But let me put it this way. Do you disagree with their assessment?

Mr. COPPOC. Yes.

Mr. CLEWELL. Yes.

Mr. GAMMELGARD. Yes.

Mr. SATTERFIELD. I noticed that you mentioned very careful studies that you had, engineering studies, and you assigned a percentage loss of gasoline on the basis of the emission controls that had been added. I observed that the witnesses who were here just preceding you, indicated that the largest percentage of fuel loss was due to weight.

I take it that you are in disagreement with that assessment?

Mr. GAMMELGARD. Mr. Satterfield, EPA ran a test on some 2,000 plus cars. All of the raw data on which they based their report claiming about a 7-percent fuel penalty due to emission controls, was made available to technical people representing API, and we came up with a figure close to twice that much. And EPA in a recent Society of Automotive Engineering meeting in Detroit revised their original figure upwards, I think, from about 7.7, or whatever it was originally to 10 percent, which was not quite as much as our 13 or 14, but at least it was a 35-percent increase in penalty over what EPA had originally said. But they certainly were good enough to let us have the raw data and statistically analyze it, and then have a good flow of information back and forth.

Mr. SATTERFIELD. Well I am no engineer, but I am an operator of an automobile. I have a 1973 model that weighs about 150 pounds more than my similar 1971 model. It has the same size engine. It has got pollution devices on it, and my gasoline penalty is more than 30 percent. I keep a very careful record of gasoline mileage.

Mr. COPPOC. Congressman Satterfield, I would like to make a comment in connection with all of these comparisons which attempt to establish a fuel economy relationship between different types of cars, whether they contain catalysts and whether they do not.

It is literally, in my estimation, impossible to get a valid set of data which will permit, for example, the type of thing which says that the 1957–67 cars at such and such a weight had such and such a fuel economy, because there have been so many changes in the construction both of the cars and the engines that the valid comparisons are very difficult. For example, GM's 13 percent is developed on a basis of a sales weighted average of their anticipated 1975 models against production 1973's. They say actually current models in their presentation.

Now, the current models of those cars do not, for example, contain a high energy ignition system. They do not contain the improved carburetion. They did not as a rule have radial tires on them, which the 1975 prototypes will.

The comparison of significance, it seems to me in this matter, is what would be the comparison in fuel economy of cars manufactured in 1975 to meet the 1975 interim standards with catalysts, to cars meeting the 1974 standards without catalysts. Now, our estimation of that is that this difference is zero, plus or minus 3 percent. I personally have made quite a study of this thing, trying to find this data. I have talked to the automobile companies about it, and I seriously doubt that there has been that comparison actually made. But it is, I think, the comparison of significance. It is the only basis upon which you can judge the fuel economies and penalties.

Mr. SATTERFIELD. It seems to me any other comparison is like comparing apples and oranges.

Thank you very much.

Thank you, Mr. Chairman.

Mr. ROGERS. Thank you.

I am not going to ask many questions because the time is very late.

I am at a loss to understand your saying that there would be a 3-percent crude loss if you take the lead out.

Is that the statement you made?

Mr. COPPOC. No.

Mr. CLEWELL. Three-percent gasoline loss.

Mr. ROGERS. Oh, 3-percent gasoline loss.

What, for the crude.

Mr. Coppoc. That converts to about 1½ to 2 percent on a crude oil basis. Now, this is what you are talking about, 91 research octane number unleaded pool.

Mr. Rogers. Yes.

Mr. Coppoc. When the research octane number goes up, if you attempt for example to regain this fuel economy by increasing compression ratio, which requires a higher octane number, and you say we are going to get that without adding lead, then the penalty against crude increases quite rapidly as you go up in octane number.

Mr. Rogers. Yes.

Now—because I think on the Senate side Mobil did testify about 1 percent. And I think Exxon——

Mr. Clewell. One to two they said.

Mr. Rogers. Well, it calculates a 1-percent loss in crude in producing lead-free for 1975, 1976. And Exxon was talking about the 91 octane of course, with very little or essentially no additional crude requirements.

Now, I think this should be clarified in the record, because it is difficult for us to know, if on one side you are going to say one thing and then here we get it different. I think we ought to have that clarified for the record.

Mr. Gammelgard. There is one basic fact.

Mr. Rogers. You can do that for the record.

[The following letter and attachments were received for the record:]

Mobil Oil Corp.,
New York, N.Y., December 7, 1973.

Representative Paul G. Rogers,
Rayburn House Office Building,
Washington, D.C.

Dear Mr. Rogers: During the API testimony before the Subcommittee on Public Health and Environment of the Committee on Interstate and Foreign Commerce on December 3, 1973, we promised to provide additional advice on the following points:

1. Possibility of Improved Recovery of Oil from Existing Fields.
2. Energy Conservation by the Oil Industry.
3. Crude Savings by not Producing 91 Octane Unleaded Gasoline.

Short statements covering each of these items are attached.

Sincerely,

Dayton H. Clewell,
Senior Vice President.

Attachments.

Attachment 1

Possibilities of Improved Recovery of Oil From Existing Fields

According to API data, 31.4 percent of our domestic known original crude oil resource in the ground of 439 billion barrels will ultimately be recovered using technology and economics prevailing in 1972.

As the National Petroleum Council's report "U.S. Energy Outlook" points out, "reserve additions resulting from improved recovery efficiency have steadily increased". Their projections to 1985 indicate that this increase will average 0.43 percent per year, reaching 36.8 percent by 1985. The study assumes an average price of $6.67 per barrel. An average price of $8 per barrel could accelerate the use of tertiary methods sufficient to raise the recovery efficiency to 38.4 percent by 1985 or an average increase of 0.54 per year. Tertiary reserve additions by 1985 are projected at 8 billion barrels at the 0.43 rate of annual increase in recovery efficiency and 18 billion at the 0.54 rate. These translate to a producing capacity of 1.7 and 3.1 million barrels per day respectively.

Stripper wells, those producing 10 barrels per day or less, produced a total of 412 million barrels of oil in 1972 (about 1.1 million barrels per day) or slightly over 10 percent of the total domestic production. Higher crude prices will extend the economic life of many of these wells, increasing their ultimate yield. For example, a 50 percent increase in crude oil prices could increase annual stripper production rate by nearly 8 percent over a four-year period, reaching a level of nearly 32 million barrels of additional oil production per year.

* * *

ATTACHMENT 2

ENERGY CONSERVATION BY THE OIL INDUSTRY

As noted during the API testimony, oil refineries consume 8 to 12% of the crude oil processed to supply their own energy requirements. Relatively small additional amounts are used in oil producing, transportation, and marketing.

With the present and future energy shortages oil companies are making serious efforts to reduce this energy consumption. As an example, Mobil has had an intensified energy conservation program during the past year. This has identified many opportunities for energy savings from operational changes and from additional capital investments. This program will result in energy savings equivalent to 13,000 Bbls/Day of crude oil or about 12% of Mobil's energy usage.

* * *

ATTACHMENT 3

CRUDE SAVINGS BY NOT PRODUCING 91 OCTANE UNLEADED GASOLINE

A refinery equipped to make 91 Research octane number gasoline will save crude if a lower octane unleaded gasoline is produced and then lead added to bring the octane number back to 91. This would be the case in 1975 if the 1974 emission standards were continued. The following comments provide explanation of this point.

In preparing to produce 91 Research ON unleaded gasoline, refiners have installed additional catalytic reforming capacity. This has been done either by expanding the capacity of existing units or by constructing new units. Also additional tankage has been provided to store and ship the new grade of gasoline.

Catalytic reforming is a unique petroleum process which makes high octane gasoline out of low octane gasoline by passing it over a catalyst at temperatures of over 900°F and pressures of 250 to 500 pounds per square inch. In any refinery the catalytic reformer is designed to produce a certain octane number at a specified thruput. However, by operation of lower temperatures, it can make lower octane number gasoline and more of it from the same thruput.

The estimate used by the API "that about 3 percent less gasoline can be made from the same amount of crude than could be made if the 91 octane gasoline were leaded" is based on the larger amount of crude used in making the higher octane number gasoline in catalytic reforming units.

Mr. GAMMELGARD. Every refinery in the country is different. They have essentially the same types of units, but not the same capabilities at all. Some plants have a 93 clear octane capability. That would be an unusually good plant. Some small, older refineries, might only be able to make 83 clear. And what it then takes to get to 91 is a completely different animal for that small refinery than it is for somebody who spent millions of dollars modernizing his plant and putting in octane producing equipment.

Mr. ROGERS. Now, you operate from a pool, do you not, and begin to build from there?

Mr. GAMMELGARD. In a refinery, yes. But the pool in a particular refinery can be different from the clear gasoline pool in another refinery by quite a few octane numbers.

Mr. ROGERS. You have a question, I believe.

Mr. SATTERFIELD. If you would yield just for one question.

Mr. ROGERS. Yes.

Mr. SATTERFIELD. You mentioned some of the smaller refineries and some of the problems they had.

Would this phase-down and the question of going to catalytic devices requiring nonleaded gasoline put any of these smaller refineries in jeopardy as far as continuing operation?

Mr. GAMMELGARD. We think it would and we so pointed out to Administrator Train in the API letter I referred to [see p. 60] saying that our figures and their own reports indicated they thought that maybe 12 to 20 small refineries might be put out of business on this lead phase-down schedule, just the phase-down schedule, not the requirement for an unleaded grade. And we pointed out that this is a pretty tough penalty, to put somebody out of business, just on phasing down lead in gasolne. And it also meant that you would lose roughly 100,000 barrels a day of crude running capacity in putting them out of business.

Well, when EPA came out with the regulations the other day, they gave the small refiners 2½ years additional time to start the phase-down schedule.

Mr. SATTERFIELD. Thank you, sir.

Mr. ROGERS. I think it would be well to document which refineries those are. The committee, I think, would be interested in pursuing that.

[See "addendum to testimony of D. H. Clewell, Mobil Oil Co.," p. 92, this hearing.]

Mr. ROGERS. Now, it is my understanding, you disagree with the automobile companies as to what the fuel savings would be from the cars coming out as of the fuel now?

Mr. COPPOC. If you study what GM actually said in their submission to the Senate Public Works, they do not come out and claim that a 1975 model manufactured to meet the 1974 standards without catalyst would be 13 percent poorer than a 1975 model manufactured to meet the 1975 interim standards with a catalyst would be.

They say that that 13 percent came from estimating the fuel economy of their 1975 catalyst-containing production on a sales-weighted basis against current models, against the fuel economy of current models. These 1973's are bad, you see.

Mr. ROGERS. Yes; but as far as the pulblic is concerned, and as far as we are concerned with fuel consumption, they claim a 13-percent fuel benefit.

Mr. COPPOC. On that basis I disagree.

Mr. CLEWELL. We disagree on that basis.

Mr. COPPOC. Well, what they actually said was, the comparison, against the 1973, the current models, you see, and that is not the comparison, as Mr. Satterfield was pointing out, that we really need.

Mr. CLEWELL. What we are saying is, they could make their 1975 cars without catalysts and not take a 13-percent penalty on those.

Mr. COPPOC. That is right.

Mr. CLEWELL. It might be 2 or 3 percent, but not 13.

Mr. ROGERS. Well, I presume there is built into the 1973 a 10-percent penalty. I think everyone admits that. You admit that.

Mr. CLEWELL. Fifteen percent.

Mr. ROGERS. You say it is now 15 in the current 1973's.

Mr. GAMMELGARD. About 13.

Mr. COPPOC. These are both estimates.

Mr. ROGERS. Yes. So you are saying that even though the 1975, the automobile claims the 13, you are saying it is a 3-percent benefit?

Mr. CLEWELL. As far as the catalyst itself is concerned.

Mr. GAMMELGARD. Attributable solely to the catalyst.

Mr. ROGERS. Yes.

Mr. CARTER. If you could excuse me a moment, Mr. Chairman.

Mr. ROGERS. Yes.

Mr. CARTER. You are using 1973 as the base year?

Mr. ROGERS. Yes; that is what they used.

Mr. GAMMELGARD. That is what GM used, which we do not think is a valid comparison here.

Mr. CLEWELL. You see, they are doing some other things besides catalysts. They are putting in high energy emission systems and better carburetors and things like this.

Mr. GAMMELGARD. Steel belted radial tires, for example.

Mr. ROGERS. But many of those are required to go along with the catalysts.

Mr. CLEWELL. No. Some manufacturers use them now.

Mr. COPPOC. That was a mistaken impression which was gained. I did not specifically hear what was said on that. It is not in the written testimony. That impression was certainly around, but it is not true.

Mr. ROGERS. Well, we will have the automobile companies here and go into that.

Mr. CARTER. Would you yield for one question on that?

Mr. ROGERS. Certainly.

Mr. CARTER. Was this increased savings, 13.5 percent, on the amount of gas consumed per mile in 1973; that is, is it a saving based on the mileage obtained in 1973?

Mr. COPPOC. Yes. They said that their 1975 cars, catalyst equipped, meeting 1975 interims would have 13 percent better fuel economy than did the current models. That was what they actually said, the 1973's.

Mr. CARTER. Well, then that would be 13 percent of—of course, we have a 15-percent loss, as you maintain, in 1971.

Mr. ROGERS. So it is cutting it 13 percent.

Mr. CARTER. No. You have to take the 13 percent——

Mr. CLEWELL. Depending on which, 13 percent of the top or the bottom, is what you are getting at.

Mr. CARTER. Yes, sir. That is right.

Mr. CLEWELL. Well, that is part of the difference.

Mr. GAMMELGARD. Could I point out another fact? We have mentioned it, but we certainly have not clarified it. And that is the sales weighted part of this prediction. If they are predicting—and I do not know what their prediction is in GM; they can say that for themselves—but if they are predicting 35 percent very small economy cars in their 1975 product mix versus maybe 20 percent in 1973, the base year, this is a different ballgame; and you are comparing apples and bananas. It just is not a fair comparison to make without explaining it fully.

Mr. ROGERS. Well, now, let me ask you this because we will go into this with the automobile companies. What have you done to comply with the order of EPA to be able to provide the unleaded gasoline by 1974?

Mr. COPPOC. We are ready. What is required is the installation of catalytic reformers and other octane improving processes in refineries of hydrotreating units and modifying other units; and then in our case it was necessary to provide for the distribution of a third grade. That means all the way from the refinery to the service station pump there is another system.

Mr. ROGERS. But the oil companies are prepared for this?

Mr. COPPOC. I cannot speak for anybody but Texaco.

Mr. CLEWELL. Mobil certainly is prepared, and I think the industry generally is.

Mr. GAMMELGARD. It is moving to be prepared.

Mr. ROGERS. So it is already an accomplished fact.

Mr. GAMMELGARD. It will be an accomplished fact I will say by July 1, 1974.

Mr. ROGERS. Well, that is when it comes on line; but I am saying as far as the steps taken in the refineries themselves, any equipment or changes, you have done this?

Mr. CLEWELL. Right.

Mr. ROGERS. So that is already done?

Mr. CLEWELL. Yes. Now, that enables us to make 91 octane unleaded.

Mr. ROGERS. Yes.

Mr. CLEWELL. But we can also take that 91 unleaded and add some lead to it and have a better gasoline because it will be higher octane, and then with an increase in compression ratio we would really begin to save on gasoline.

Mr. ROGERS. Yes; but your cars are not being made to run except on 91 and have not been since 1973. We just had that testimony.

Mr. COPPOC. 1971.

Mr. ROGERS. 1971.

Mr. CLEWELL. Right, but we are saying they could change some of them by 1975, probably all of them by 1976.

Mr. ROGERS. But that does not get over the immediate problem here of 1974.

Mr. CLEWELL. No, nothing does that.

Mr. COPPOC. Nothing does that. Those cars are in the——

Mr. CLEWELL. Except conservation.

Mr. COPPOC. Except a suggestion from over here that you might want to just take them off; and I am not going to recommend that.

Mr. ROGERS. Well, I am not sure. There is testimony that that would cause a penalty, too, in building your 1974 or 1973, which you say is 15 percent. So I do not know where that would get us.

I was concerned about distribution. How are you going to get all of this out? I understand it can be done by using a flush technique to get the lead out of your tank in the filling station to get it prepared, and then of course maybe by a different size nozzle or——

Mr. COPPOC. That is in the regulation.

Mr. ROGERS. It would seem to me if we are in a shortage it might be easier to get a system like that going than if we had an overage, because you will have some tanks that probably would be empty which they could use to flush out some of your tanks; cars you would not have to use because you do not have as much to deliver.

So this might be a very good time to make this adjustment, would it?

Mr. CLEWELL. No. I would say no.

Mr. ROGERS. Why not?

Mr. CLEWELL. Let me say this. Although we are prepared to do it, say we do not have to do it, we can make more gasoline as a result of not having to do it.

Mr. ROGERS. You can do what?

Mr. CLEWELL. We can make more gasoline. We can make 91 leaded, and this would give us more gasoline than we have now.

Mr. ROGERS. Well, it depends on what savings after that is put in the automobile. Now, I understand the testimony from Exxon and Mobil has been 0 to 1 percent. Now, we are not losing the fuel use. It is simply that into gasoline, is that not correct? In other words, you have a byproduct that you can use. Maybe LPG or different types of energy could come from that, could they not?

Mr. CLEWELL. Yes. That is only partially true, though. The thing is it takes about 8 to 12 percent of the energy that goes into a refinery that we consume right there just to do our processing.

Mr. ROGERS. Yes, I understand that?

Mr. CLEWELL. Now, when we have to do more processing to make this octane unleaded instead of leaded, it usually takes a little more energy that you just burn up and it is lost.

Mr. ROGERS. Yes, but would it not take a lot more energy if you went up to a higher octane?

Mr. CLEWELL. Unleaded, yes.

Mr. ROGERS. What about leaded?

Mr. CLEWELL. No.

Mr. ROGERS. It would not require any more?

Mr. CLEWELL. No. You just add lead. It is an additive you put in.

Mr. ROGERS. No more fuel required in the refinery?

Mr. CLEWELL. No.

Mr. ROGERS. Just the adding of lead.

Mr. CLEWELL. Right.

Mr. COPPOC. May I come back? You asked a question in a manner in which maybe we misunderstood; but you see, even though we are equipped as an industry presumably to make 91 research octane number clear gasoline, we could make, using a less stringent operation on the catalytic reformers which are the basic units which were put in in order to do this, if you operate those at a lower conversion level, you do not come out with as high a clear octane number; then you get more of that. It is the same old business. It is about 2 percent more that you get when you—instead of coming out with 91 research octane number clear as the whole thing, you come out around 88, 87, and in some cases in our calculations you can even go down to 85 and add 2½ grams of lead to a gallon of gasoline and come back up to the octane you want.

Now, this is what you can gain right now. If you do not have to make the 91 research octane number unleaded available, then there is this additional processing loss which would be available to you. It is a loss when you make it unleaded. It is a gain when you can lead it and come back. That is available immediately.

Mr. ROGERS. Yes.

Mr. HEINZ. Would the chairman yield for one question at this point?

Mr. ROGERS. Certainly.

Mr. HEINZ. Regarding the penalty that we are experiencing, or we may expect to experience in the calendar year 1974 with respect to unleaded gasoline. I believe if I have my assumptions right you said that the difference between going from an 88½-percent octane, research octane, to a 91-percent octane unleaded was on the neighborhood of 2-percent penalty in terms of crude. Is that right?

Mr. COPPOC. About.

Mr. HEINZ. One to two, something like that; 1 to 2 percent?

Now, clearly not all of the automobiles are going to require either low lead or unleaded gasoline in 1974. What do your statistics indicate is going to be your penalty, the penalty attributable to unleaded gasoline next year in 1974 in terms of barrels per day crude oil equivalent, if you can, or gallons of gasoline, if you will.

Mr. COPPOC. Go ahead, Dayton, if you have got it.

Mr. CLEWELL. Maybe you could add to it, but there are two things to consider—first, the number of cars that are going to be equipped with catalysts; then in addition to that, some of the automobile manufacturers are saying that even though some of the cars will not have catalysts on, they are still going to equip all their cars with small diameter fill pipes so that they will take unleaded gasoline only, even though some may not require it because they won't be catalyst equipped.

You will have to ask them why they are going to do it, but nevertheless, they are.

Mr. HEINZ. Thank you. I will try that.

Mr. CLEWELL. So this would mean then there is quite a bit of unleaded gasoline required for the 1975 cars as they come out.

Mr. HEINZ. What do your marketing people tell you you are going to sell in terms of unleaded gasoline next year, or in 1974, calendar 1974, or if it is easier for you, the 1975 model year?

Mr. CLEWELL. Calendar 1975.

Mr. HEINZ. You would like to do calendar 1975, which is more than a year from now?

Mr. CLEWELL. Right.

Mr. HEINZ. You do not have a figure for 1974? Can you give me both 1974 and 1975?

Mr. HEATH. Sure; 1975 is about 25 percent of the total gasoline will be unleaded, total demand.

Mr. HEINZ. That is your sales? Your sales will be 20 percent unleaded?

Mr. HEATH. Mobil sales will be less than that. Mobil sales will be about 14, but there are some companies in the industry who only market two grades of gasoline; and when they put out their unleaded grade, they are going to have a lot of their regular customers using it because they have no choice, and their sales will be much higher.

We are estimating the industry will be 20 percent. Mobil will be 14.

Mr. HEINZ. But most gas stations have three grades. You are going to be selling 14 percent because that is all there is.

Mr. HEATH. But there are going to be a few companies that are going to be selling 40 or 50 percent.

Mr. HEINZ. And that is in 1975, so it would be less in 1974.

Mr. HEATH. In 1974 it will be much less, because currently with no catalyst cars it runs around 3 percent or less, and the 1975 models come out in what, September, October—it would be very little. Calendar 1974 will probably be less than 5 percent unleaded gasoline.

Mr. HEINZ. Three to five percent?

Mr. HEATH. Yes.

Mr. HEINZ. OK.

From those numbers I guess we can work out what the actual penalty is in terms of barrels. I am not enough of a sharp pencilman to be able to do it.

Mr. HEATH. We submitted to the Senate committee, we said 16,000 barrels a day of crude in 1975.

Mr. HEINZ. 16,000 barrels a day in 1975 crude equivalent.

Mr. HEATH. Yes.

Mr. HEINZ. All right.

That is very helpful. I thank you very much, and I thank you, Mr. Chairman.

Mr. ROGERS. Thank you.

What is the fuel cost to produce tetraethyl additives?

Mr. COPPOC. I do not know.

Mr. GAMMELGARD. I do not know.

Mr. CLEWELL. You would have to ask Ethyl that.

Mr. ROGERS. What do you pay for it?

Mr. HEATH. Two-tenths of a cent per gram.

Mr. ROGERS. And how much will this be reduced would you think under unleaded and reduced lead regulations? Would this be a reduction of costs to you and then to the consumer, I presume?

Mr. HEATH. To get octanes any other way is more expensive so it is going to cost the company more or the customer more when we have to take lead out and make the same quality.

Mr. ROGERS. Well, now, just a minute. How many are you going to require? How much of the higher octane are you going to have to make when they have been making 91 octane motors since 1971?

Mr. COPPOC. They could all be leaded. They could all use leaded gasoline.

Mr. GAMMELGARD. And have been.

Mr. ROGERS. But they do not have to be. They can also use unleaded, can they not, 91?

Mr. COPPOC. They can use anything that has 91 research octane.

Mr. ROGERS. Well, that's what I understand; so now how much are you going to produce of 91 octane gas and how much are you going to produce then of the higher 98 octane gas?

What would Mobil do?

Mr. HEATH. We have estimates of what our demand will be in 1974–75 for these other grades.

Mr. ROGERS. Yes.

Mr. HEATH. I do not remember them exactly at this point.

Mr. ROGERS. Well, I understand. I would not expect you to. But on a general run, what would they be, just in broad figures?

Mr. HEATH. In 1974 we are running about 34 percent premium, which would be 99 octane, and around 3 percent of a low lead grade, and the rest of it is regular at 93 octane. Does that answer your question?

Mr. ROGERS. Well, that is for 1974. That is just when you are coming into the required regulations. What about 1975 and 1976?

Mr. HEATH. In 1975 the premium demand goes down a little bit because this is largely for old cars. It will probably come down to about 30 percent. We said 20 percent unleaded, and the balance will be leaded regular.

Mr. ROGERS. Which requires a small amount of lead, is that right?

Mr. HEATH. We are using something around 2 grams today.

Mr. ROGERS. About 2 grams. Would you anticipate doing that?

Mr. HEATH. We would anticipate staying at fairly high lead levels because we can make more barrels of gasoline that way.

Mr. COPPOC. That is right.

Mr. ROGERS. How much more could you make if you can make unleaded at 91?

Mr. HEATH. I am not sure I understand the question, sir.

Mr. ROGERS. Well, as I understood it, it takes a certain amount of energy to make 91 octane for your own use. It requires no more to make 98, no more fuel.

Mr. COPPOC. Not if you do it with lead.

Mr. GAMMELGARD. Not if we can use lead.

Mr. ROGERS. By just putting lead in it.

Mr. CLEWELL. Right.

Mr. ROGERS. So it is not going to be any more energy use either way.

Mr. HEATH. Well, let's talk about this 50-percent regular. It is 93 octane. If we take the lead out of that, it is down around 86 octane.

Mr. ROGERS. Well, can you not make it 91 like you do the other?

Mr. CLEWELL. No; we would lose gasoline.

Mr. ROGERS. How much do you lose going from 91 to 93?

Mr. HEATH. Unleaded?

Mr. ROGERS. Unleaded.

Mr. HEATH. About 1 percent.

Mr. ROGERS. About 1 percent. Would that be general throughout the industry?

Mr. HEATH. I would think that it is difficult——

Mr. COPPOC. Pretty much, if I could take that guess. That is kind of the number most people say.

Mr. ROGERS. Sure. All right.

What are we now exporting in petroleums?

Mr. GAMMELGARD. I do not think I have an answer to that, Mr. Chairman.

Mr. ROGERS. Who would know?

Mr. GAMMELGARD. The Interior Department, I believe, has been gathering some data on who is exporting what to where; and I think there definitely have been some instances recently where cargoes of distillates have been sold in the European market because of a very fancy profit on it. And I do not know the companies. We do not keep figures on who sells what to who. But the Department of Interior undoubtedly has this documented. It is a very small quantity, but nevertehless it is something that emotionally runs rather high.

Mr. ROGERS. I just wondered, because we had been asked that. Do any of the companies know, are any of your companies exporting?

Mr. COPPOC. Not that I know of.

Mr. HEATH. Exporting what sort of product?

Mr. COPPOC. When you void the little bit that goes back and forth across the Canadian border, for example——

Mr. ROGERS. Fuel oil, distillate products, and gasoline.

Mr. CLEWELL. Lubricants, lube oils.

Mr. ROGERS. Lubricating oils?

Mr. CLEWELL. Lubricants themselves.

Mr. ROGERS. Yes.

Mr. GAMMELGARD. I do know of one export deal that has been going on for some years now that just came to mind. That is out of southern California's refining center in the Los Angeles area where, because of the sulfur restrictions in the atmosphere there, they cannot sell some 5,000 barrels of residual fuel oil they make, so the Mexican powerplant down the coast some 50 or 60 miles is very pleased to buy it and have been doing this for some years. And maybe this winter people in Los Angeles might think that that would be pretty nice stuff to have to keep their lights burning.

Mr. ROGERS. I wondered. I hear that perhaps more crude could be extracted from existing wells. You will have to tell me as I have no way of knowing. It has been said that when a rate of recovery reaches a certain point, the well is capped because the profit is not as great, although there is still some profit margin to be made.

Is that true?

Mr. CLEWELL. That is partially true.

Mr. ROGERS. Do we have an estimate of what the reserves from those wells are where we have recovered a part but could not perhaps recover more?

Mr. CLEWELL. Well, it is probably available, but I do not have it now; but I would like to make sort of a general statement on that point now.

Mr. ROGERS. Sure.

Mr. CLEWELL. Today on the average in the United States—and I am talking about the southern 48 States—the recovery of oil from the reservoir will run around 31, 32 percent, meaning the rest is still down there. Now, the reason that that much is left there, it is an economic limit to try and get more out. For example, in the case of a water flood where you are putting water in a reservoir and 98 percent of the material coming out is water and only a little bit is oil, you lose money to continue so you stop.

Now, however, as the price of crude oil goes up, you can go further than that. Your economic limit is stretched out. There are techniques, for example, that we have had under development in research for a number of years for putting chemicals into the flood waters, which will enable you to wash out a greater percentage of the oil. The only thing is those chemicals cost money.

Now, as soon as the price is up enough to pay for those chemicals that we have to put in there, we will be able to recover more oil.

Now, as far as what does this mean, estimates have been made that perhaps you could have as much as a half of a percent or maybe three-quarters of a percent increase per year; in other words, run this 31½ maybe up to 32 in a year as a result of these price increases, or not necessarily price increases, but by the application of these new techniques.

They feel that in a matter of years, let's say, 15, 20 years and so on, we may get that 32 percent up to around 40, 42, 45 even; and all of this is a percentage of a pretty big base of oil that we have down there. So it is an important consideration in terms of increasing our supplies.

Mr. ROGERS. That is very helpful. And I think if you could for the record give us some projections of what that would mean, like as you say, as a beginning, maybe half of 1 percent, if you could project that for us.

Mr. COPPOC. That is an extremely difficult question you just asked for.

Mr. ROGERS. I am sure it is not easy.

[The following information was received for the record:]

U.S. CRUDE OIL RESERVE DATA

Source: "Reserves of Crude Oil, Natural Gas Liquids, and Natural Gas in the United States and Canada and United States Productive Capacity as of December 31, 1972."

Vol. 27, May 1973—Published jointly by: American Gas Association, American Petroleum Institute and Canadian Petroleum Association.

DEFINITIONS

Proved Reserves of Crude Oil. Proved reserves of crude oil as of December 31 of any given year are the estimated quantities of all liquids statistically defined as crude oil, which geological and engineering data demonstrate with reasonable certainty to be recoverable in future years from known reservoirs under existing economic and operating conditions.

Reservoirs are considered proved if economic producibility is supported by either actual production or conclusive formation tests. The area of an oil reservoir considered proved includes: (1) that portion delineated by drilling and defined by gas-oil or oil-water contacts, if any; and (2) the immediately adjoining portions not yet drilled but which can be reasonably judged as economically productive on the basis of available geological and engineering data. In the absence of information on fluid contacts, the lowest known structural occurrence of hydrocarbons controls the lower proved limit of the reservoir.

Reserves of crude oil which can be produced economically through application of improved recovery techniques (such as fluid injection) are included in the "proved" classification when successful testing by a pilot project, or the operation of an installed program in the reservoir, provides support for the engineering analysis on which the project or program was based.

Estimates of proved crude oil reserves do not include the following: (1) oil that may become available from known reservoirs but is reported separately as "indicated additional reserves"; (2) natural gas liquids (including condensate); (3) oil the recovery of which is subject to reasonable doubt because of uncertainty as to geology, reservoir characteristics, or economic factors; (4) oil that may occur in untested prospects; and (5) oil that may be recovered from oil shales, coal, gilsonite and other such sources.

Crude oil potentially available from these sources is reported as "indicated additional reserves." The economic recoverability of these reserves is not considered to be established with sufficient conclusiveness to allow them to be included in proved reserves; however, if and when improved recovery techniques are successfully applied to known reservoirs, the corresponding indicated additional reserves will be reclassified and added to the inventory of proved reserves. The "indicated additional reserves" are reported separately from "proved" reserves to provide continuity to the proved reserves' statistical series.

Indicated additional reserves do not include reserves associated with acreage that may be added to the area of a proved reservoir as the result of future drilling.

Indicated Additional Reserves. With the present state of industry technology, certain quantities of crude oil (other than those defined and reported as proved reserves) may be economically recoverable from the following potential sources:

Known productive reservoirs in existing fields expected to respond to improved recovery techniques such as fluid injection where (a) an improved recovery technique has been installed but its effect cannot yet be fully evaluated; or (b) an improved technique has not been installed but knowledge of reservoir characteristics and the results of a known technique installed in a similar situation are available for use in the estimating procedure.

DATA

Summary data pertaining to reserves of crude oil in the United States for the year 1972 as follows:

CRUDE OIL

(Thousands of Barrels of 42 U.S. Gallons)

Total proved reserves of crude oil as of Dec. 31, 1971	38,062,957
Additions to proved reserves in 1972:	
Revisions of previous estimates	820,107
Extensions of old reservoirs	459,311
New reserves discovered in new fields	123,210
New reserves discovered in new reservoirs in old fields	155,220
Total proved reserves added in 1972	1,557,848
Total	39,620,805
Less production during 1972	(3,281,397)
Total proved reserves of crude oil as of Dec. 31, 1972	36,339,408
Net change in proved reserves during 1972	(1,723,549)
Additional information:	
Indicated additional reserves as of Dec. 31, 1972	5,190,257

[See also letter dated Dec. 7, 1973, from D. H. Clewell, Mobil Oil Corp., p. 64, this hearing.]

Mr. HEINZ. Mr. Chairman.

Mr. ROGERS. Yes, Mr. Heinz.

Mr. HEINZ. I have a question, and I will be brief. Just to follow what you are working on there, I just wanted to get one assumption clear. We were talking about a 16,000-barrel-a-day penalty for 1975, as I recall, if that is correct. If we assume consumption of 17—excuse me—of 7 million barrels per day in 1975, my calculations show that that would work out to a bit less in 1975 than one-quarter of 1 percent of all of the gasoline that we might expect to use in that year.

Would that be correct?

Mr. HEATH. It sounds reasonable.

Mr. COPPOC. You see, that was for a projected 20 percent unleaded gasoline.

Mr. HEINZ. That was based on the 20 percent.

Mr. COPPOC. So if you multiply the 16,000 barrels a day by 5 you come up to 80,000 barrels a day, which is in the range that we had estimated for the total. It is not too far off.

Mr. HEINZ. So that would be correct. And if you multiplied that—conversely, if you multiplied that 16,000 barrels by 365 days you would get about 6 million barrels, which at the astonishing rate we utilize petroleum in this country is 8 hours' supply.

I thank you.

Mr. ROGERS. Now, my last question: What does it actually require in the way, say, of barrels of oil to refine barrels? Somewhere in the range of 2 barrels for 10, or what?

Mr. GAMMELGARD. Fuel equivalent?

Mr. ROGERS. Yes.

Mr. GAMMELGARD. About 10 percent.

Mr. Coppoc. About 10, depending on what you are getting out of your refinery, how complicated it is, whether you have petrochemical establishments or not. We take the number 8 to 12 percent, and it covers everything from a nice little simple fuel refinery up to a pretty complicated one.

Mr. Rogers. Has this amount been reduced over the years?

Mr. Clewell. It is being reduced pretty rapidly right now.

Mr. Rogers. I just wondered if any research had been done to reduce it.

Mr. Clewell. Oh, yes.

Mr. Rogers. Would you let us have something on the record for that, what progress we are making?

Mr. Gammelgard. I think we can. At the midyear refining meeting this year there were two papers given which had a target of 15-percent reduction in the fuel consumer refinery as being an attainable, a tough goal.

[Testimony resumes on p. 88.]

[The articles referred to follow:]

Oil Refinery Design Concepts for Energy Conservation

(By J. E. Hayden and W. H. Levers)[1]

Introduction

The concept of energy conservation in a refinery is not new—we're merely dealing with the 1973 model. The basic problems and incentives continue to be pertinent—we strive for minimum use of energy consistent with related economic factors. However, superimposed on this are environmental aspects which, while always present, have now assumed a considerably more significant role than previously.

Scope

This paper analyzes in depth the criteria followed on initial construction and recent expansion of our Pascagoula Refinery now rated at 280,000 BPOD of crude.

In developing the various data we have analyzed and grouped related factors to facilitate obtaining both an overall view of the energy picture and detailed several specific examples of system and equipment selection. Data are based on actual studies developed during plant design studies.

Thus our analyses and conclusions are based on criteria applying to Pascagoula. However, the principles involved are universal, so long as one understands that there are typically several alternatives near optimum approaches to effective energy utilization in a large refinery.

Fundamental Concepts

As a means of setting the scene for consideration of specific examples there are several fundamental concepts that should be borne in mind. They provide an overall view of the refinery and include the following:

1. A refinery can be considered as a mammoth energy refining process. We take crude oil, add conditioning energy, and produce saleable fuels and petrochemical products of various types.

2. A refinery can be considered on the basis of an overall heat balance, with internal systems then singled out and considered as contributing to the total.

3. Based on (1) above, our analyses consider the use of *Btu's* as the fundamental energy unit, without initially concerning ourselves with the source (i.e., fuel oil, natural gas, process gas, electrical energy, etc.)

The foregoing concepts facilitate optimizing refinery energy balance criteria and permit ready comparison of a refinery with other manufacturing processes utilizing large amounts of energy in the form of oil, gas, coal, and nuclear reactions. Thus we not only develop criteria for analyzing and optimizing a refinery

[1] Standard Oil Company of California, Engineering Department, San Francisco, Calif.

as such, but we can also compare our industry's ability to process energy as compared to others. As you will see, the petroleum industry compares quite favorably. This is a message we need to get across to the public and government groups, particularly during the current period of impending energy crisis, when fuel oil offers the best short-term solution.

The Overall Picture

Fortuuately for our purposes our Pascagoula Refinery is largely a fuel producer so relatively minor adjustments were required to compensate for non-fuel producing facilities such as a paraxylene plant, sulfur plant, and a large ammonia plant. Figure 1 is an overall block flow diagram illustrating the refinery's major plants and product slate.

A typical overall refinery energy heat balance case is shown on Figure 2. The input of methane and nitrogen from the air in addition to the crude oil accounts for the output of 238,000 BPD as compared to the 225,000 BPD input. However, the energy content of the end product is less than the input energy, so we don't have the equivalent of perpetual motion. In any event, the saleable products are produced at the expense of a rather modest 9% of the total energy input for a 91% conversion efficiency. By comparison the Lurgi coal gassification process has a 68–70% conversion efficiency. [1]

Carrying on beyond this, the *best* thermal power plants have a 40% conversion efficiency—i.e., coal to electrical energy. The *1970 average* for thermal power plants was only 30% [2]. Admittedly electrical energy is a very versatile "product," but petroleum-based fuels and petrochemicals are also versatile and are produced more efficiently and economically from oil than from coal.

If we consider useful work produced in the form of space heating, the overall energy cycle via the refinery route comes out at about 60–70% efficient in heating applications, as shown on Figure 2. By comparison the comparable thermal power plant—electrical energy cycle has about 26% *overall* efficiency based on the 1970 average for thermal plants. This increases to 34% overall efficiency using a top thermal plant electrical energy generation efficiency of 40%. This is true even though electrical energy can be converted to heat with 100% efficiency.

Optimum Energy Balance

One of the primary factors in conserving energy in the Pascagoula Refinery was early evaluation of alternative basic heat cycles. Only by having maximum design flexibility can we hope to economically conserve energy. Processes must be flexible to the point that they do not prematurely dictate what energy cycles are feasible. Fuel supplies and utility systems must be the result of economic energy evaluation not dictated by other factors such as arbitrary decisions to purchase power, install in-plant fired boilers, etc. Both the foregoing and following design concepts attest to the results possible through implementation of this approach.

Comparison of Alternative Energy Cycles

In developing areas where refineries can conserve energy there are three basic options available:

1. Improved mechanical energy conversion in drivers for pumps, compressors, and fans.
2. Improved process heat recovery.
3. Improved process energy conversion using better catalysts, etc. (not considered within the scope of this paper).

We will concentrate on the first two categories. Alternatives are initially considered from an overall refinery standpoint, then for specific representative plants, and finally for various energy loops within a plant. Through this sequential approach we are able to arrive at more objective answers than if the sequence is reversed. That is, we do better to let the answer develop, as compared to an approach that starts with plant energy loops and proceeds to synthesize the overall picture. This latter approach can lead to higher costs and some rather unfortunate steam balance and electrical energy combinations.

As a starter, we will consider several overall alternative energy cycles. In analyzing these we will find that our existing refineries are reasonably efficient, but that there is considerable room for improvement. To set the stage, Figure 3 brackets the alternatives and illustrates what can be considered as the extreme cases.

First of all it shows that our energy cycle for refinery utilities could theoretically have 76% efficiency if waste heat streams were more effectively utilized. On the other hand a case utilizing essentially all-electric motor drivers operating on purchased power would have only a 23% efficiency. Refineries actually operate some place between these limits.

The most efficient cycle consists of a gas turbine driven generator with a full supplemental fired waste heat boiler. High-pressure steam is produced and let down through a steam turbine to the pressure level required for process heating while driving another generator. This cycle is optimum for refinery use if all the heat of condensation can be used for process heating.

However, in a typical refinery and in particular at Pascagoula, not all of this steam can be utilized for process heating and must be used in condensing turbines. This significantly reduces the cycle efficiency. Figure 4 illustrates the balance of turbines, motors, and process steam consumption achieved at Pascagoula to date. The 38% overall efficiency achieved is considered below the ideal cycle but well above that for a typical electric cycle as well as higher, we believe, than most refineries.

The four gas turbine generators coupled with waste heat boilers are a big factor in the energy picture. They also reduced initial capital investment since they are owned and operated by the local utility company. They are located in the refinery where steam can be economically supplied to the refinery system. The utility company supplied boilers made it unnecessary to add any new refinery boilers following initial plant construction. Furthermore, having a full capacity backup tie to the utility comapny's main 110 kv power grid coupled with a programmed refinery load shed system provides above average electric power reliability for critical plants.

We hope in the future to improve the cycle efficiency even more. With the addition of more power and steam demand Gas Turbines 3 and 4 can be fully loaded and their waste heat boilers fully supplementary fired. This will significantly increase this cycle efficiency.

In addition, a CO boiler generating high-pressure steam which would be let down through a steam turbine coupled to a generator could be installed. Since CO is waste steam, the heat recovered from it is not considered as input energy into the refinery. For this case the resulting cycle efficiency based on the power and steam out over the fuel gas required is greater than 100%.

The net effect of fully loading Gas Turbines 3 and 4 and adding a CO boiler is to increase the overall efficiency to 42% as shown on Figure 5. As the cost of energy increases we will find more ways to justify higher efficiencies.

In considering alternative means of minimizing refinery energy consumption, the Pascagoula hydrogen manufacturing plant is worth reviewing. Figure 6 illustrates the variety of combinations available in this one plant. It contains examples of several interesting possibilities, while other plants typically have only some of these. The plant has an unusually high utility cycle efficiency of 71%, which is considerably better than the 42% obtained on the cycle shown on Figure 5 and approaches the 76% cycle efficiency considered as the optimum practicable shown on Figure 3.

The refinery also includes a large ammonia plant that generates 900 psi steam and utilizes another gas turbine compressor driver plus a 32,000 hy steam turbine. The net effect of this arrangement is that the plant is nearly self-sufficient from a utility standpoint. Because of its similarity to the hydrogen plant we have not included any detail on it. Since ammonia is not a "fuel", we included it in the overall refinery balance by taking the equivalent energy in the hydrocarbon components had they been converted into fuel products.

The foregoing should provide some basis for analyzing plants that exist in other refineries to see how well they compare to examples given.

Heat Recovery Possibilities in a Crude Unit

So far we have dealt with energy conservation in more or less general terms. More specific examples are illustrated in Figures 7 and 8. These figures compare the energy requirements for our No. 2 Crude Unit with No. 1, built some seven years earlier. Both units have the same rated capacity, so the comparisons are particularly meaningful. Furthermore, since crude units are large energy consumers, the degree to which the refinery conserves energy is largely dependent on the design concepts built into the crude units. Accordingly, the following paragraphs and Figures 7 and 8 compare these two plants.

Factors Considered

The basic design objective for the Pascagoula No. 2 Crude Unit had been to duplicate the existing No. 1 Crude Unit. The No. 1 Crude Unit had a demonstrated maximum throughout of 145,000 BPOD. As the design of the No. 2 Crude Unit progressed, however, many improvement opportunities were recognized. Those having payouts were incorporated in the design. Most of the design improvements were aimed at increasing energy conservation within the plant. The primary design changes improving energy conservation were:

1. Optimization of the crude preheat train including product coolers.
2. Use of a common air preheater to increase furnace efficiencies.
3. Optimization of the vacuum column overhead system.
4. Use of a double-ended condensing turbine to drive the crude feed and booster pumps instead of electric motors.
5. Steam stripping of the HSGO sidecut instead of using a direct fired reboiler.

These design improvements are discussed below.

Optimization of Crude Preheat Train

The design of the crude preheat train for the No. 2 Crude Unit included optimization of both individual exchanged performance and overall heat utilization within the plant. Optimization of individual exchanger performance was fostered by Company developments in crude preheat fouling control and by the development of reliable clean rating methods and guidelines for optimizing shell-side design developed by Heat Transfer Research Inc. These developments permitted designing crude preheat exchangers for the No. 2 Crude Unit with approximately 35 percent higher heat transfer coefficients than were attained in the No. 1 Crude Unit. Optimization of overall heat utilization involved balancing investment and operating costs for furnaces, crude preheaters, steam generators, and product coolers to obtain the most economic heat distribution between these various types of equipment.

A comparison of the No. 2 Crude Unit preheat train at a nominal rate of 135,000 BPD is shown in Figure 7. The result of the No. 2 Crude Unit preheat train optimization is an increase of about 10 percent in heat recovered as crude preheat. At 135,000 BPD this amounts to 43 MBH and is reflected by a reduction of this same amount in furnace duty.

Most of the increase in crude preheat is accomplished at the low temperature end of the preheat train. Generaly, heat from cooler product streams that is not recovered as crude preheat is lost to the atmosphere, making recovery of heat at the low temperature end of the train particularly attractive. At the high temperature end of the preheat train the hot product streams can be used to generate steam after exchange with the crude. Less steam is generated in the No. 2 Crude Unit than the No. 1 Crude Unit, but this does not represent a reduction in recovered heat when considering the total refinery heat balance. The Isomax and FCC streams are normally fed directly to their respective processing units hot. In the No. 2 Crude Unit steam generation is traded for more efficiently utilized process heat for subsequent units. The change in distribution of heat and improved crude preheat recovery in the No. 2 Crude Unit result in the No. 2 Crude Unit throwing away a total of 63 MBH less than the No. 1 Crude Unit at 135,000 BPD.

Furnace Air Preheating

The size of the furnaces for the No. 2 Crude Unit was further reduced by the addition of an air preheater. A common air preheater serves both the atmospheric and vacuum furnaces in the No. 2 Crude Unit. The No. 1 Crude Unit atmospheric and vacuum furnaces exhaust directly to the atmosphere at approximately 700° F. The average furnace efficiency in the No. 1 Crude Unit is 79 percent (based on the lower heating value for the gas fuel) as compared to 92 percent in the No. 2 Crude Unit. The net reduction in the required heat release for both the atmospheric and vacuum furnaces due to the improved efficiency is 65 MBH at 135,000 BPD.

Optimization of Vacuum Column Overhead System

The vacuum system for the No. 1 Crude Unit vacuum column was initially designed to produce a column top-tower operating pressure of 1.4 psia. Changes in operating conditions had resulted in raising the operating pressure to 4.0 psia by the time the No. 2 Crude Unit was designed. The No. 2 Crude Unit vacuum overhead system was designed for the higher pressure. This automatically led to greater efficiency and lower operating costs for the No. 2 Crude Unit.

Additional incentive for energy conservation resulted from the No. 1 Crude Unit vacuum system not having been designed incorporating the best available vacuum technology. The systems for both crude units contain precondensers and two stage ejectors with inter- and after-coolers. The various elements for the No. 1 Crude Unit were designed separately and pieced together. The precondensers in particular were very inefficient. The elements for the No. 2 Crude Unit were designed as a system by one of the more experienced vacuum equipment vendors. The change in operating pressure and improved system design has resulted in a reduction of about 15 MBH in energy requirements for No. 2 Crude Unit as compared to No. 1 Crude Unit.

Feed and Booster Pump Condensing Turbine Drivers

The primary feed and booster pump driver for the No. 2 Crude Unit is a highly efficient double-ended 150# condensing turbine driver. The spare pumps are driven by individual condensing turbines. All the turbines are served by a common condenser. In the No. 1 Crude Unit the primary pumps are motor driven and the spares are driven by 600#—40# turbines. At high crude throughputs the No. 1 Crude Unit spare booster pump must be operated. This dumps about 50,000 lb/hr of relatively undesirable 40# steam into the refinery system (the refinery tends to have excess 40# steam).

Investment in the turbines and condenser for the No. 2 Crude Unit was offset by not having to provide a high voltage feeder, transformers, and switchgear to the plant. All other power requirements for the plant are at the 460V or lower level. Condensing turbines using low pressure steam are more economical than electric motors spared by back pressure turbines.

Steam Stripping HSGO Sidecut

The No. 1 Crude Unit was originally designed with two sidecut strippers having fired reboilers for HSGO cuts. Subsequent operation showed that steam stripping of HSGO improves the recovery of jet fuel from this cut and is more efficient than fired reboiler stripping. The No. 2 Crude Unit was designed for steam stripping only and for just one HSGO cut. This eliminated the investment in a stripper and two fired reboilers. The No. 1 Crude Unit had already been converted to steam stripping when the No. 2 Crude Unit was designed so that there was little difference between energy demands for the units. A conservative estimate of the operating savings by steam stripping rather than using fired reboilers, however, is 10 MBH.

No. 2 Crude Unit Energy Balance

The net effect on annual operating costs of all the design changes between the No. 1 and No. 2 Crude Units is shown in Figure 8. This tabulation shows utility requirements for each unit based on current operating procedures at a throughput rate of 135,000 BPD. It also assigns dollar values to operating costs based on current fuel prices. The annual operating cost for the No. 2 Crude Unit is 18 percent less than for the No. 1 Crude Unit. Note particularly that as the cost of fuel increases, annual savings increase nearly in direct proportion. This in turn means that additional energy conservation steps can be justified economically as the cost of energy increases. While added energy costs are hardly an advantage, we can take some comfort in realizing that environmental control requirements can be more readily achieved on an economic basis under the situation where energy costs are increasing.

Summary

From this analysis of a typical modern refinery, it becomes apparent that we have always been inherently conscious of energy conservation. In recent years our awareness has increased and will continue to increase during the '70's. Much has been done, but there is much to be done. Our goal should be to more closely approach theoretical energy cycles while satisfying economic and environmental criteria.

It is evident that many alternatives exist. Energy conservation can lead to significant savings in investment and operating costs while concurrently satisfying environmental needs if we're clever enough. Key factors to success are our continued awareness and diligent efforts to effectively explore all feasible alternatives.

Thus, the petroleum industry has a challenge to meet in this climate of rising costs and environmental concern. Our ability to conserve energy while reducing costs and satisfying environmental restrictions will, to a large extent, determine how well we as individuals, our companies, and the petroleum industry, fare in the years ahead.

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AOKNOWLEDGEMENTS

The authors wish to express their appreciation for the data and comments provided by their associates in the Engineering Department of the Standard Oil Company of California.

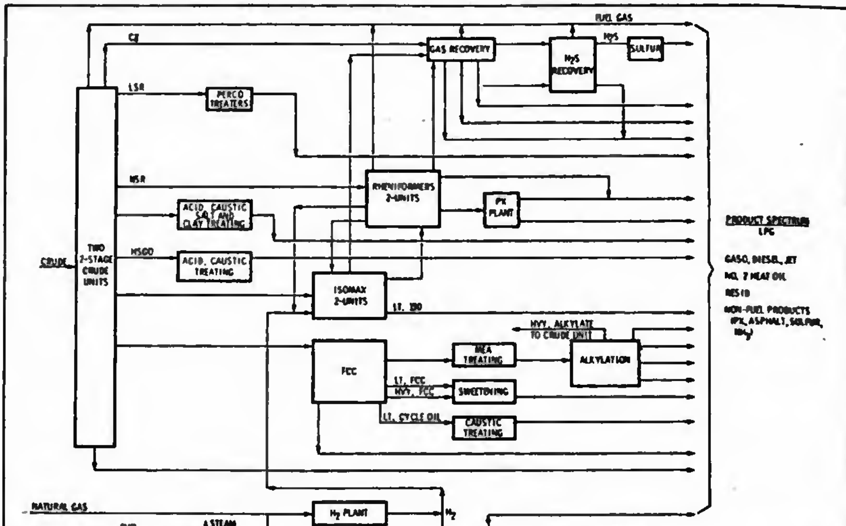


FIGURE 1
REFINERY BLOCK FLOW DIAGRAM

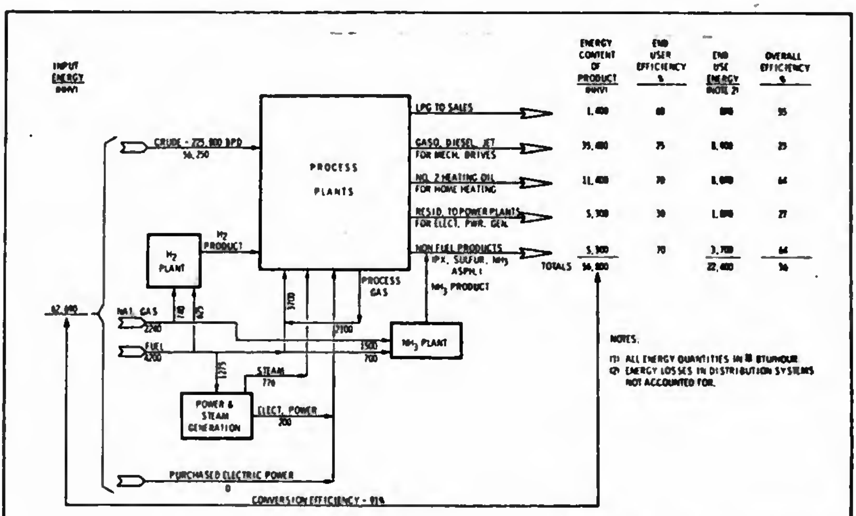


FIGURE 2
OVERALL REFINERY ENERGY BALANCE
PASCAGOULA REFINERY

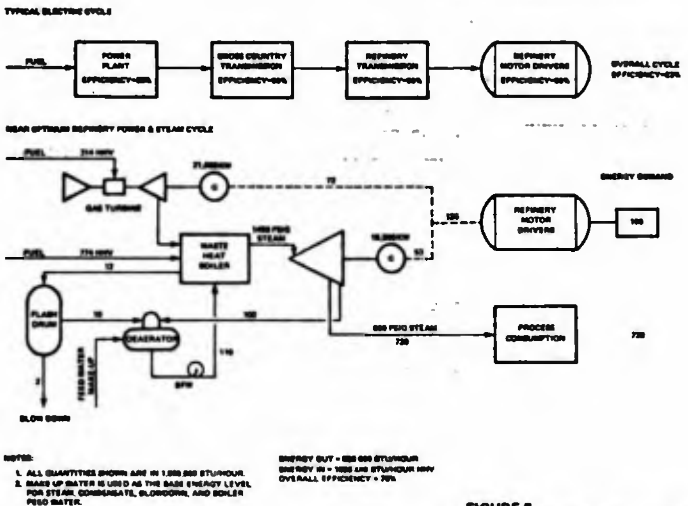


FIGURE 3
COMPARISON OF NEAR OPTIMUM ENERGY CYCLE vs. TYPICAL ELECTRIC CYCLE

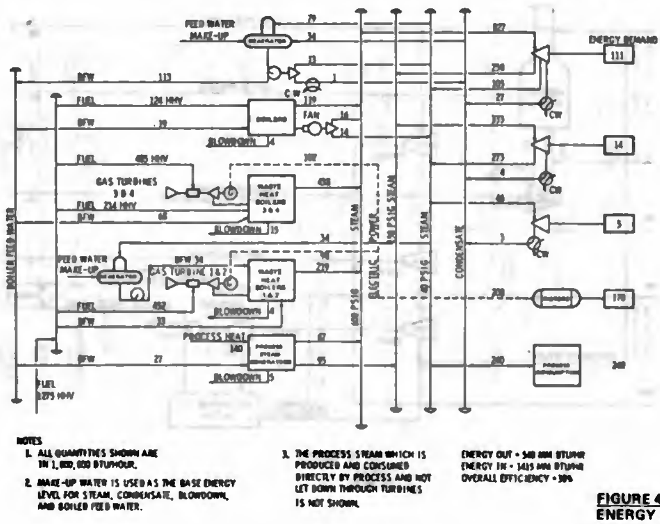
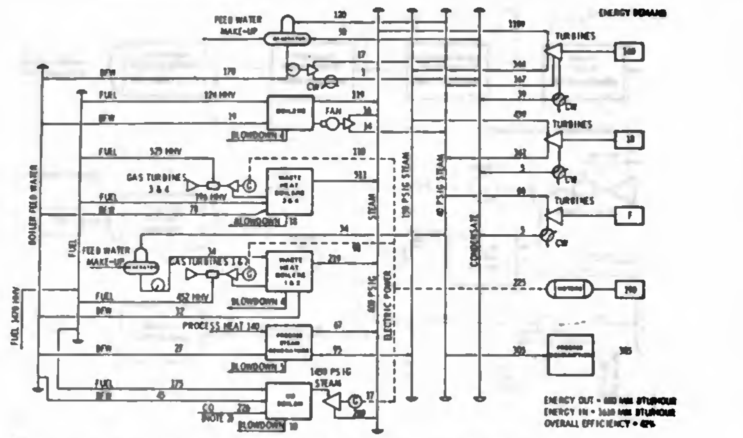
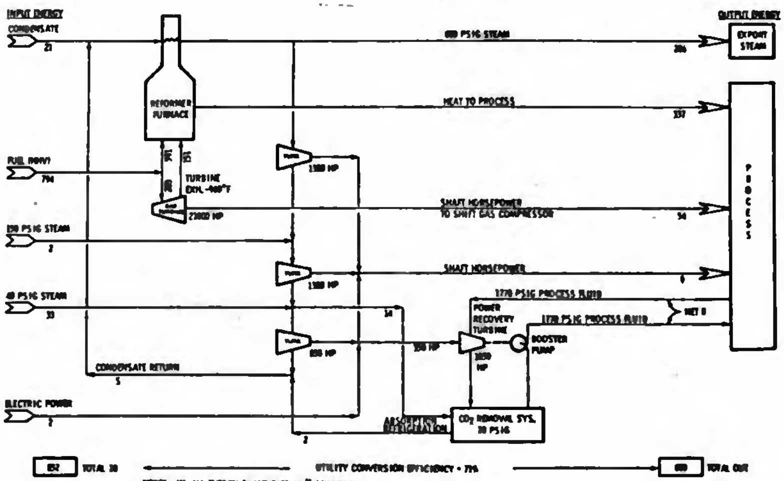


FIGURE 4
ENERGY BALANCE STEAM & POIWER



NOTES:
1. ALL QUANTITIES SHOWN ARE IN 1,000,000 BTU/HOUR.
2. THE ENERGY OF CO IS CONSIDERED WASTE HEAT AND IS NOT INCLUDED IN THE "ENERGY IN" USED TO CALCULATE OVERALL EFFICIENCY.
3. MAKE-UP WATER IS USED AS THE BASE ENERGY LEVEL FOR STEAM, CONDENSATE, BLOW DOWN, AND BOILER FEED WATER.
4. THE PROCESS STEAM WHICH IS PRODUCED AND CONSUMED DIRECTLY BY PROCESS AND NOT LET DOWN THROUGH TURBINES IS NOT SHOWN.

FIGURE 5
ENERGY BALANCE STEAM & POWER FUTURE CASE



NOTES: (1) ALL ENERGY QUANTITIES IN MM BTU/HOUR.
(2) MAKE-UP WATER IS USED AS BASE ENERGY LEVEL FOR STEAM & CONDENSATE.

FIGURE 6
ENERGY BALANCE HYDROGEN PLANT

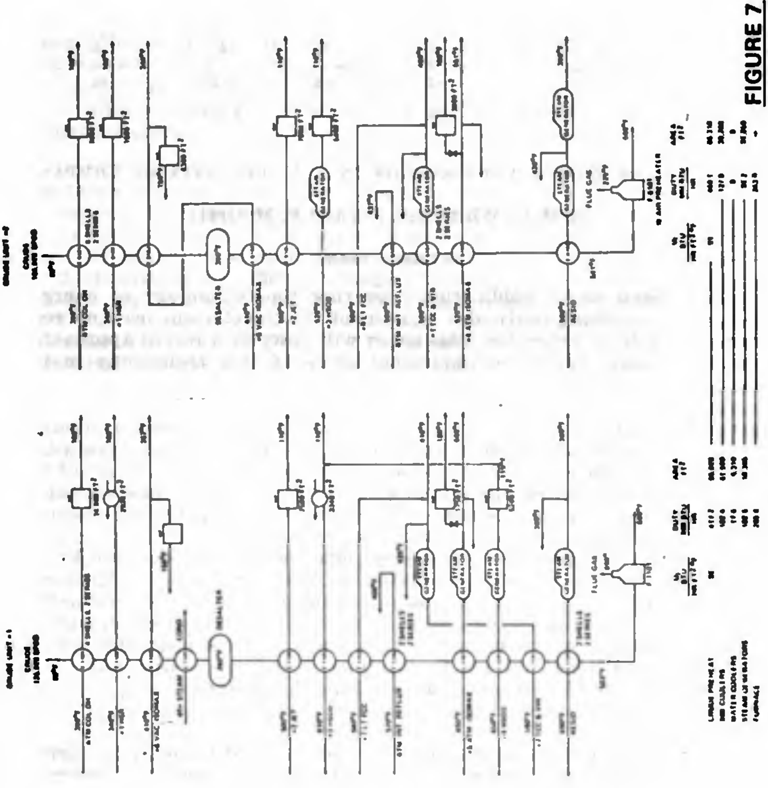


FIGURE 7
COMPARISON OF FEED PREHEAT TRAINS FOR CRUDE UNITS 1 & 2

FIGURE 8.—COMPARISON OF ENERGY REQUIREMENTS FOR NOS. 1 AND 2 CRUDE UNITS OPERATING AT 145 000 BBL/D

[Dollar amounts in thousands]

Utility item	Consumption		Annual operating costs at 55 cents per 1,000 SCF Gas and 7 mil power		
	No. 1 crude. equivalent	No. 2 crude. MM Btu/hr	No. 1 crude	No. 2 crude	Yearly savings
Electrical	13	8	$226	$143	$83
Cooling water	2	1	80	42	38
Fuel gas	597	477	2, 710	2, 160	550
Boiler feed water	21	12	121	71	50
Steam:					
600 lb	118	61	581	300	281
150 lb	−116	31	−477	128	−605
40 lb	0	−52	0	−164	164
Condensate	−5	−8	−27	−43	16
Total	630	530	3, 214	2, 637	577

Planning for Energy Conservation in a Multi-Refinery Company

(By M. G. Whitcomb, Jr., and F. M. Orri)[1]

INTRODUCTION

There have been many publications covering the technology of energy conservation, and describing particular equipment for the efficient use and recovery of energy in petroleum refineries. This paper will describe a recent approach taken by Exxon Company, U.S.A. to implement more of this technology in its five refineries.

This is not the first effort of its kind undertaken by the Company. Under normal management practices, each refinery is responsible for the control of operating costs, and many steps have been taken through the years to reduce costs through improved energy efficiency. In the past two years, however, the prospect of rapidly increasing fuel costs has led our refineries to make an overall assessment of the present consumption of fuel, steam, and electricity, the potential savings, and to define specific implementation steps to conserve energy.

The incentives for improvement in energy efficiency are substantial. For example, consider a typical U.S. refinery of 100,000 barrels per day throughput, consuming 600,000 Btu per barrel. At a fuel cost of 50¢ per million Btu, the refinery could save $1.5 million annually in the cost of fuel by a 15% reduction in energy consumption, a reduction which is well within reach of most refineries. Of course, there would be additional outlays for equipment and manpower, but a refinery similar to the one cited in this example could find a substantial number of attractive efficiency projects, both through additional capital investment and improved operating practices.

This paper will cover the criteria that were established for efficient energy consumption, the results of a screening survey of the 1971 levels of consumption relative to those criteria, and the program that is being developed to move toward the criteria.

CRITERIA FOR ENERGY CONSUMPTION

The first step taken was to develop screening criteria for efficient energy use in refinery process units. Total energy consumption was expressed in terms of fuel equivalents, using standard fuel equivalencies for steam and electric power of 1,750 M Btu per M lb of steam and 9 M Btu per kwh, respectively. Factors for the consumption of energy as functions of throughput were estimated for each type of process unit, and for each refinery. The data used in establishing these consumption criteria were actual or design consumptions of a number of relatively new refineries, including domestic and overseas refineries of Exxon Corporation.

[1] Exxon Company, U.S.A., Houston, Tex.

Actual energy costs of operating refineries have been published by Nelson. [1] The data were for 1961 energy consumption, and the average age of the refineries from which the data were taken was not disclosed. These energy consumption levels were substantially higher than those from which the efficiency criteria for this study were developed.

The screening criteria may be conveniently summarized for any refinery in terms of its Nelson Complexity Factor, [2] a measure of the relative intensity of processing. In Table 1 are shown estimated energy consumptions in terms of equivalent heat consumption per barrel of input for medium and high efficiency refineries at several levels of the Complexity Factor. The high efficiency consumption rate is typical of that for a new, modern refinery design as it would be built today. The medium level of efficiency is typical of refineries built 10–15 years ago. It is recognized that the Nelson Complexity Factor, which is representative of investment differences among refinery process units, bears only an approximate relationship to energy consumption. In spite of this limitation, it can be used to get an indication of the relative energy efficiency of complete refineries, and to estimate potential energy savings. The levels of consumption in the screening criteria are reasonable targets at present, but may need revision in the future based on experience.

REFINERY SURVEY

Using these criteria, each of the Company's refineries conducted a survey of its actual consumption, and compared the results to efficient criteria. As shown in Table 2, a survey was made of consumption by unit and for the total refinery. In addition, the source of energy losses was sought by comparison of key output operating conditions to efficient design conditions. For example, furnace and boiler stack temperatures were measured and compared to design temperatures of 350–400° F. Furnace and boiler excess air was measured and compared with design excess air rates of 5 to 10% for gasfired units (higher for liquid fuel). Temperatures of process streams being cooled by air or water were measured and compared to 250° F. These comparisons offered an independent check of measured or estimated energy consumption and indicated where there might be potential action steps to improve energy efficiency. In the 1971 survey, the identified sources of loss accounted for about 65% of the difference between actual consumption and the high efficiency criteria.

The results, summarized in Table 3, showed that the 1971 energy consumptions of the Company's five refineries averaged 33% above the high efficiency level. This placed them near the medium efficiency level as expected due to their average age. Average furnace stack temperatures were 500–800° F, compared to 350–400° F for an efficient new furnace. The identified energy "losses" versus high efficiency criteria were about equally divided among furnace inefficiency, cooling various process streams above 250° F with air and water, and inefficient use of stream and condensate.

ENERGY CONSERVATION PROGRAM

After results of the survey were analyzed, a decision was made to devote additional attention and effort to energy conservation. Task groups were set up at the larger refineries, and specific energy consumption targets were adopted by each refinery. In the first year of the program, accomplishments were primarily in areas of problem identification, project screening and development, and target setting. Some early reductions in the consumption of fuel and steam were achieved through operating practices, but additional energy requirements for new process units that were brought on stream offset these, and kept the total energy consumption per unit of throughput about constant.

In the program over the next five years, recovery of about 65% of the identified losses is expected, with resulting energy consumption of about 10 to 15% above the high efficiency level. If the refineries are successful in meeting these targets, energy consumption will be reduced about 15% from the 1971 level. The sources of recovered energy are predicted to be as shown in Table 4. Improved efficiency of furnaces and recovery of additional heat from process streams are expected to be the largest areas for future savings, accounting together for over half the predicted improvement. Other recovery of waste heat from the exhaust gases of fired turbines, gas engines, and boilers will add about 10%. Improved utilization of steam and water would add another 25%, through better insulation of steam lines and fittings, repair of steam leaks, discontinuing the idling of spare steam turbines, recovery of steam condensate, and preheating boiler and crude desalter feed water. A number of other measures, including more catalytic cracking unit flue gas expansion turbines, would make up the remaining 10%.

Although the program has just begun, it is apparent that none of the five concerns listed by Kozeny and Stanton [3] can be ignored. These are:

- Management participation and goal setting.
- Identification of energy usage and loss.
- Evaluation of design, operating, and maintenance practices.
- Publicity and education.
- Follow-up and assessment.

The task cannot be accomplished by any one person or any departmental group, but must receive the cooperation of management, technical personnel, process operators, and mechanical craftsmen. For this reason, it places a critical challenge on the ability of a complex organization to meld the contributions of these people into an effective program.

REFERENCES

1. W. L. Nelson, "Refinery Complexity Controls Utility Costs," *The Oil & Gas Journal*, Vol. 61 [16] 135 (1963).

2. W. L. Nelson, "Refinery Complexity Examined," *The Oil & Gas Journal*, Vol. 70 [44] 72 (1972).

3. O. A. Kozeny and E. J. Stanton, "Energy and Material Conservation in Refineries," *The Oil & Gas Journal*, Vol. 70 [45] 82 (1972).

TABLE 1.—ENERGY CONSUMPTION VERSUS REFINING CAPACITY

	Estimated energy consumption, M Btu/Bbl divisor	
	Medium efficiency	High efficiency
Overall refining complexity:[1]		
6	525	380
7	600	435
8	675	490
9	760	550
10	850	615

[1] Using Nelson factors but with no adjustment for multiple units.

TABLE 2.—CRITERIA FOR EVALUATING EFFICIENCY

	Design
1. Comparison with theoretical energy consumption:	
Per unit	
Total refinery	
2. Comparison actual operating conditions with design basis:	
Furnace:	
Stack temperature	350° to 400° F.
Excess air	5 to 10 percent.
Cool process streams (air/water)	Below 250° F.

TABLE 3.—RESULTS OF 1971 ENERGY CONSERVASION SURVEY

Energy consumption above "high efficiency" criteria:	
Average	33 percent.
Range	23 to 59 percent.
Average refinery furnace stack temperature: Range	500° to 800° F.

TABLE 4.—FUTURE PROGRAM

Sources of recovered energy:	Percent
Improved furnace efficiency	25
Recovering heat from process streams cooled by air or water	30
Other waste heat recovery (turbine or engine exhaust boilers etc.)	10
Reduce steam consumption and loss	10
Preheat desalter and boiler feed water, recover steam condensate	15
Other	10
Total	100

[See letter dated December 7, 1973, from D. H. Clewell, Mobil Oil Corp., p. 64, this hearing.]

Mr. ROGERS. Does anyone have any questions?

Mr. CARTER. Mr. Chairman, I have one. I want to return to a point we brought out a while ago. Suppose a car of 1971 got 15 miles per gallon; in 1973 we had a 15 percent penalty on that. Then that car, 1973, got 12.75 miles per gallon, which I really do not think they do since I have one, but then if we install a catalytic converter in 1975, we get a 13 percent increase. And the way my figures come out we would still not be getting as many miles per gallon as we were in 1971, is that correct?

Mr. COPPOC. This is correct.

Mr. CARTER. All right.

The thing about it is that it is a little bit confusing when you get those figures, but certainly you do not get as many miles as you get out of the 1971 car.

Mr. COPPOC. In this connection, Mr. Chairman and Mr. Carter.

Mr. CARTER. Yes, sir.

Mr. COPPOC. Mr. Preyer, I believe, asked a question about the fuel economy of stratified charge engines.

Mr. CARTER. Yes, sir.

Mr. COPPOC. Texaco has a controlled combustion system which is a stratified charge engine which we have quite a bit of experience on; and we have made vehicles with this engine meet the original 1976 standards. And with your permission, I would like to submit a little statement. I can tell you now, but I will submit a little statement which will give the background on that.

Mr. ROGERS. It would be very helpful.

[The following letter and attachments were received for the record:]

TEXACO INC.,
Beacon, N.Y., January 10, 1974.

HON. PAUL G. ROGERS,
House of Representatives,
Washington, D.C.

DEAR SIR: During the Subcommittee hearings relative to the automotive emissions standards and their impact on the U.S. petroleum demand, which were held during the week of December 3, 1973, I was asked to supply information on our stratified charge engine. This concept, designated as the Texaco Controlled Combustion System (TCCS), utilizes direct cylinder injection of the fuel similar to a diesel engine in conjunction with spark ignition.

Three inherent features of this stratified charge engine concept are: low emissions, good fuel economy, and an ability to operate on a wide range of fuels encompassing such commonly available products as gasoline, diesel fuel, home heating oil, and jet fuel. This combination, of course, could be significantly important to our requirement for low emissions and good utilization of our petroleum resources.

I am attaching a detailed discussion of the data we have obtained to date on both and Army Jeep which was developed under contract with the Tank Automotive Command of the U.S. Army, and the work that we have done on a subcompact car, a Chrysler Cricket, powered by a TCCS engine.

If you have any questions on this matter, please contact me.

Sincerely,

W. J. COPPOC,
Vice President, Environmental Protection.

Attachment.

TEXACO CONTROLLED COMBUSTION SYSTEM FUEL ECONOMY AS RELATED TO EXHAUST EMISSIONS

The Texaco Controlled-Combustion System (TCCS) is an engine concept employing a fuel injection, spark ignition, stratified charge combustion. It has demonstrated excellent fuel economy and the ability to operate on a wide range of fuels including gasoline, diesel fuel and jet engine fuel. Moreover, it exhibits inherently low gaseous pollutants. Almost two years ago, under a USA TACOM contract, TCCS, in a 4-cylinder engine installed in a military "Jeep," demonstrated to the Environmental Protection Agency the ability to satisfy the original 1976 exhaust standards which are very stringent standards. Last spring, the TCCS, after 50,000 miles of operation, retained low emissions with moderate maintenance again demonstrating its ability to EPA to satisfy these low emission levels.

Without emission controls the "Jeep," using its standard carburetted engine, recorded 15.3 miles per gallon of fuel. With a TCCS turbocharged engine, hydrocarbons, carbon monoxide, and nitrogen oxides were 33 percent, 90 percent, and 55 percent lower, respectively, in the TCCS vehicle without emission controls than the standard carburetted vehicle. At the same time, the TCCS exhibited a 60 percent increase in miles attained per gallon of fuel. (Refer to the first two lines of attached Table II.)

Equipped with emission controls, the TCCS complied with the original 1976 Federal standards. The same TCCS-powered vehicle recorded 16.2 miles per gallon, 33 percent below the uncontrolled TCCS vehicle but nearly 6 percent better than the uncontrolled carburetted-engine vehicle. (The fuel economy at each of several intermediate degrees of emission control is also shown in Table II.)

Over the past few years, Texaco has evaluated the effect of emission control devices on several vehicle installations of this 4-cylinder TCCS engine. Results of some of these tests are shown in the accompanying tables.

Fuel economies were measured while driving the Federal cycle used for determining exhaust emissions. Two different procedures were used: the more accurate by weighing the actual amount of fuel used in driving the 11.1 miles of this cycle, and the second by analyzing the exhaust constituents and calculating the fuel that should have been used to obtain these emission levels. In the accompanying tables, the first procedure is labeled (Wt.) and the second (CO_2). These tabulations also indicate the type of emission controls used for each test.

EPA recorded the penalty in fuel consumption in the USA TACOM "Jeep" in tests run at their Ann Arbor, Michigan facility. Results, shown in Table I attached, indicated a 39% increase in fuel used in order to reduce just slightly the overall emissions to satisfy target levels, particularly the nitrogen oxides standard.

Texaco further examined the TCCS fuel penalty in meeting various levels of exhaust emissions. These tests were conducted in two vehicles: the "Jeep" with a TCCS turbocharged engine equipped with a 4-speed manual transmission referred to above and in Table II, and a subcompact passenger car with a TCCS naturally aspirated engine equipped with an automatic transmission.

Table III for the TCCS-powered compact shows results generally similar to the TCCS-powered "Jeep." All runs were made with exhaust catalytic treatment, with various degrees of combustion retard, exhaust back pressure (EBP), and exhaust gas recirculation (EGR) to gradually lower emissions. In these tests, a 26% increase in fuel consumption, compared to the TCCS engine without emission controls, was required in order to meet the emission target.

The penalties associated with different degrees of exhaust emission control discussed above are related to the fuel burning characteristics of internal combustion engines in general. The data provide a basis for evaluating the fuel economy sacrifice that emission controls impose. Excessively low emission standards have a truly detrimental effect on fuel resources.

Although the TCCS type of stratified charge engine has inherent fuel economy advantages of considerable magnitude and naturally low exhaust emissions, the application of stringent exhaust emission controls to this type of engine carries a high fuel economy penalty similar percentagewise to the penalty suffered by carburetted engines.

Texaco believes it is imperative to:

1. Provide time for technology of this type (or equivalent performance) to achieve widespread use in the automobile industry.
2. Optimize the balance between exhaust emissions, ambient air quality, and fuel consumption.

TABLE I.—MILITARY JEEPS WITH TCCS NATURALLY ASPIRATED ENGINE—EPA DATA

Test condition	Emissions (grams per mile) HC	CO	NO$_x$	Fuel economy MPG (CO_2)
TCCS Jeep with catalyst, combustion retard, low rate EGR	0.50	0.14	0.70	21.9
TCCS Jeep as above but high rate EGR	.37	.24	.31	15.8
Federal standards	.41	3.4	.40	

TABLE II.—MILITARY JEEP WITH STANDARD ENGINE AND TCCS TURBOCHARGED ENGINE—TEXACO DATA

	Emission controls: Catalyst	Combustion retard	EGR	Emissions (grams per mile): HC	CO	NO$_x$	Fuel economy, MPG (weight)
Standard carbureted engine: None	No	No	No	4.50	73.2	3.22	15.3
TCCS turbocharged engine:							
None	No	No	No	3.13	7.00	1.46	24.3
Step 1	No	8°	No	3.24	6.43	1.29	22.4
Step 2	No	8°	Low rates	3.60	6.69	.84	20.5
Step 3	Yes	8°	Moderate rates.	.22	1.29	.66	19.4
Full	Yes	13°	High rates	.35	1.41	.35	16.2
Federal standards				.41	3.4	.40	

TABLE III.—SUBCOMPACT PASSENGER CAR POWERED BY TCCS NATURALLY ASPIRATED ENGINE WITH CATALYST—TEXACO DATA

	Emission controls: EBP increase	Combustion retard	EGR	Emissions (grams per mile): HC	CO	NO$_x$	Fuel economy, MPG (weight)
Catalyst only	No	No	No	1.07	0.84	1.89	25.8
Step 1	No	9°	No	.73	1.18	1.20	23.3
Step 2	Yes	9°	Low rates	.61	.85	.99	22.5
Step 3	No	9°	Moderate rates	.59	.64	.55	22.6
Full	Yes	9°	High rates	.36	1.15	.38	20.0
Federal standards				.41	3.4	.40	

Mr. COPPOC. There is potential within the stratified charge engine for significant improvements in fuel economy. The more stringent you make the exhaust emission requirements, the more penalty you pay on fuel economy. That is also true with the stratified charge engine.

Mr. SATTERFIELD. I just have one question to follow up what Dr. Carter said. When you talk about your percentage increase, you are talking about your lower figure; therefore, you need a higher percentage to get consumption economy up to where it was.

Mr. GAMMELGARD. You are right.

Mr. CLEWELL. I would like to add just one statement to Mr. Carter there. When he says he gets his 13 percent by putting on a catalytic converter, the catalytic converter will not give you the 13 percent. It is a lot of other things that are going to do it, too.

Mr. CARTER. Yes, sir.

Mr. ROGERS. Any other questions?

Thank you very much. And we may get back to you with other questions, if we may. Thank you for being here.

Mr. GAMMELGARD. Fine. Thank you.

[Testimony resumes on p. 98.]

[An addendum to Mr. Clewell's testimony follows:]

ADDENDUM TO TESTIMONY OF D. H. CLEWELL, MOBIL OIL CORPORATION

1. ENERGY ASPECTS: PRODUCTION OF DESULFURIZED UNLEADED GASOLINE; CURRENT AND FUTURE GASOLINE DEMANDS; AND POTENTIAL USE OF LEADED GASOLINE IN CARS HAVING CATALYTIC DEVICES

a. Summary

The estimated total energy savings from continuing the 1974 auto emission standards are as follows:

1975 no savings.
1976 55,000 bbls/day of crude oil.
1980 833,000 bbls/day of crude oil.
1985 1,713,000 bbls/day of crude oil.

The rate of crude oil savings increases with time because the demand for unleaded gasoline would increase each year, and because of fuel economy decreases associated with the auto emission standards for 1976 and later years.

The overall savings summarized above are the total of savings from four different aspects. These are as follows:

CRUDE OIL SAVINGS

[Barrels per day]

	1975	1976	1980	1985
Savings in oil refinery from not producing unleaded gasoline	16,000	30,000	77,000	153,000
Savings in refinery from not desulfurizing unleaded gasoline	None	None	96,000	180,000
Savings in gasoline consumption by maintaining 1974 auto emission standards	[1] 16,000	None	220,000	460,000
Savings in gasoline consumption by use of leaded octane number gasoline	None	25,000	440,000	920,000
Total savings		55,000	833,000	1,713,000

[1] Loss.

b. Savings from not producing unleaded gasoline

The refinery production of unleaded gasolines requires the use of processing steps instead of lead to obtain the required octane number levels. These process steps require energy to operate and involve some losses in gasoline yield. The amount of crude oil which could be saved by producing leaded instead of unleaded 91 octane number gasoline is estimated to be equivalent to be between 1% and and 2% of the unleaded gasoline produced. We have used 1.5% and estimate the following specific savings of crude oil:

Crude Oil Savings from not producing unleaded gasoline

	Barrels per day
1975	16,000
1976	30,000
1980	77,000
1985	153,000

Most refineries are now equipped to produce the quantities of 91 O.N. unleaded gasoline required in 1975 and 1976. However, this does not reduce the potential crude oil savings noted above; as in a period of crude oil shortage, the equipment would either not be operated or would be operated at reduced severity. There is however a minimum unleaded octane number level which a modern refinery can produce. This is in the range of 84 to 86 octane number. Thus in the above case, the crude oil savings would be essentially the same whether the leaded grade assumed is 91 or 93 octane number, as the difference between the grades would be largely in lead content.

Inherent in the above estimate is the following forecast of the probable total demand for unleaded gasoline.

Total Unleaded Gasoline Demand

	Percent
1975	14
1976	25
1980	56
1985	100

The following factors were considered in this forecast:

1. Usage of unleaded gasoline by some cars not having catalytic converters was assumed. These included the following:

1974 and older cars that are now using unleaded or new low lead grades of gasoline—about 2.5% in 1975.

1974 and older cars which will start to use unleaded gasoline after July 1, 1974 because service stations with only two grades will eliminate the grade now being used by some motorists in order to introduce an unleaded grade—about 4% in 1975.

The usage of unleaded gasoline by 1974 and older cars will gradually decrease as over the years.

1975 model cars without catalysts but certified for use on unleaded gasoline (Ford and American Motors).

2. Light trucks under 6,000 pounds wt. were assumed to use unleaded gasoline on the following schedule.

1975–76	all GM vehicles
1977–80	all vehicles

3. Alternate engines were assumed to be introduced having the following fuel requirements.

Rotary engines:

Imported models will use leaded gasoline.

GM models will use unleaded gasoline.

Stratified charge—all models will use leaded gasoline.

4. Late model cars are driven more miles per year than older cars.

Some of the possible savings, such as those from fuel economy savings in 1975 and later model cars, apply only to that portion of the unleaded gasoline used by the 1975 and later model cars. This portion of the demand was estimated to be as follows:

Unleaded gasoline consumption by 1975 and later models

	Percent
1975	7.5
1976	19.0
1980	55.0

c. Savings from not desulfurizing unleded gasoline

As noted in Mr. Clewell's formal testimony, the desulfurization of unleaded gasoline causes an increase of about 1% in crude consumption if all gasoline is desulfurized. In most of our examples, only a portion of the gasoline is desulfurized. In U.S. refineries, gasoline production is about 50% of the crude oil refined. Therefore, the crude penalty for desulfurization can also be expressed as equivalent to 2% of the volume of gasoline desulfurized. On this basis, the crude oil losses for the desulfurization of unleaded gasoline would be as on the following page:

	Barrels per day
1975	none
1976	none
1980	96,000
1985	180,000

There would be no penalty in 1975 and 1976 because desulfurization facilities could not be constructed that soon.

d. Savings from maintaining the 1974 auto emission standards

In estimating the crude oil savings resulting from relaxed emission standards, permitting use of leaded gasoline, we have assumed freezing emission standards at 1974 levels. The specific fuel economy assumptions for each model year cars meeting the 1974 standards are as follows:

For 1975 models—A 3% loss in fuel economy versus 1975 emission standards.

As discussed below, this compares with an estimate by Ford and Chrysler of a 3% difference due to the use of catalysts and a General Motors estimate of 13% which we do not find understandable.

For 1976 models—A 5% gain in fuel economy versus 1976 interim emission standards.

This compares to a 9% loss for 1976 over 1973 models given by Mr. Misch in his discussion on November 5, and Mr. Cole's indication that the gains he estimated for 1975 would "decrease significantly" in 1976.

For 1977 to 1985 models—A 5% gain in fuel economy versus 1977 emission standards modified to an oxides of nitrogen standard of 2.0 grams/mile, or the same as the 1976 interim standards. If this were at a more restrictive level, such as the present 1977 standard, the crude oil savings would be higher.

The fuel economy factors discussed above apply only to the unleaded gasoline used in 1975 and later model cars and not to that used by older cars. The crude oil savings estimated to result from maintaining the 1974 emission standards are as follows:

Crude oil savings by use of 1974 emission standards instead of emission schedule discussed above

	Barrels per day
1975	16,000 loss
1976	none
1980	220,000
1985	460,000

Both Senator McClure and Senator Domenici raised questions pertaining to the effect of emission control devices on the fuel economy of automobiles in particular comparisons between Mobil's estimates and General Motor's estimates. The following discussion provides more details than could be provided in the oral discussion, and explains the basis for the crude oil savings estimated above.

Since actual experience on 1973 models is now available, the first comparison of interest is the loss in fuel economy between 1967 and 1973 models as published by both Mobil [1] and General Motors, [2] and the causes attributed to these losses.

[In percent]

	GM	Mobil
Loss in fuel economy between 1967 (no emission control) and 1973 cars	20	20
Allocation of losses:		
Modifications for emission control:		
Spark timing and air-fuel ratio changes	10	6
Exhaust gas recirculation	3	2
Lower compression ratio	2	7
Loss due to emission control	15	15
Vehicle weight increases	5	5
Total loss	20	20

General Motors and Mobil are in agreement on both the total loss and the loss due to emission control. The major difference is in the allocation of the losses due to compression ratio and spark timing plus air-fuel ratio changes. Mobil assigned 7% to compression ratio while GM assigned only 2%.

The actual average compression ratio of 1973 cars is about 1.1 units lower than that of 1967 cars. Engine design textbooks for years have stressed that compression ratio is a major factor in the thermal efficiency of engines. During the last 20 years, many technical studies of the actual effects of compression ratio on fuel economy have been published, including a number by General Motors.[3] A recent review of this literature [4] indicated an average loss in fuel economy of 6.3% with a reduction of 1.0 compression ratio. This is consistent with the Mobil estimate of a 7% loss for a 1.1 reduction in compression ratio. The GM estimate of a 2% loss due to the compression ratio change appears to be in conflict with the laws of thermodynamics, and extensive published literature.

The difference between Mobil and GM in the amount of fuel economy loss attributed to compression ratio is important in the estimation of how much fuel

[1] "Impact of Automotive Emission Regulations on Gasoline Demand," D. H. Clewell and W. J. Koehl, Koehl, API paper 730515, May 15, 1973, Letter W. P. Tavoulareas to R. M. Fri, August 6, 1973.

[2] Attachment 7 of E. N. Cole Testimony of November 5, 1973.

[3] D. F. Caris and E. E. Nelson, "A New Look at High-Compression Engines" SAE Transactions, Vol. 67 (1969) Paper 61A.

C. F. Kettering, "More Efficient Utilization of Fuels" SAE Quarterly Transactions, Vol. I, (1947).

[4] "Information on Fuel Economy of Recent U.S. Cars" W. E. Bettoney of DuPont, August 22, 1973.

economy can be improved by engine readjustment when a catalytic converter is installed, as the loss due to compression ratio cannot be regained as long as 91 octane gasoline is used.

The second comparison of interest is that for 1975 model cars with catalytic converters. GM in Attachment 7 of their testimony estimates that their 1975 cars with catalytic converters will have a fuel economy loss of 9% over the 1970 models or a recovery of 11% from 1973. (The 13% recovery quoted by Mr. Cole in his testimony was over 1974 cars. While both Ford and Chrysler forecast that their 1974 cars would have about 3% better fuel economy than their 1973 cars, Mr. Cole forecast that 1974 GM cars will be 2% worse than their 1973 cars.)

For 1975 model cars, we agree that some improvement in fuel economy can be obtained by engine adjustment when catalysts are employed. Since our estimate of losses due to engine adjustment in 1973 models was 6% and some of this will probably be recovered in 1974 models, we estimated that 3% could be regained by catalysts in 1975 models.

In his testimony on November 5, 1973, Mr. Misch of Ford said their 1975 models equipped with catalysts would have a 3% improvement in fuel economy over their 1974 models. Mr. Riccardo agreed with the Ford estimate.

Thus the effect of catalysts on the changes in fuel economy of 1975 model cars versus 1974 models is as follows:

General Motors	13 percent gain
Ford and Chrysler	3 percent gain
Mobil	3 percent gain

In summary, we find the GM claim of a 13% gain in fuel economy with 1975 cars to be inconsistent with both sound engineering analysis and with the statements of both Ford and Chrysler. The GM estimate is understandable to us only if it contains fuel economy gains from factors unrelated to the use of catalysts. Such things might include high energy ignition systems, improved carburetors, radial tires, and less acceleration performance. These improvements would, of course, apply to engines with and without catalytic devices. Under questioning by Senator Clark on November 5, Mr. Cole did concede that the 13% gain in fuel economy, which GM estimated for 1975 models, was not all due to the use of a catalyst.

c. Savings from use of high octane leaded gasolines and high compression ratio engines

Since 1971 most new cars have been designed to operate on 91 O.N. unleaded gasoline. Under present plans all 1975 models will be designed for this grade of gasoline. If the auto emission standards were frozen at the 1974 levels, leaded gasolines and higher compression ratios could be used to increase engine efficiency. To demonstrate the potential advantages of such an action, the following example has been prepared.

Basis: 91 O.N. Unleaded Gasoline

Case A—Addition of 0.5 gms lead/gallon increases octane number to 94 and permits a reduction of 4% in fuel consumption.

Case B—Addition of 2.5 gms lead/gallon increases octane number to 98 and permits a reduction of 11% in fuel consumption.

In these examples, no refinery investments are required over those necessary to meet the present schedule of emission standards. In fact, to the extent that crude oil is saved, there would be some reduction in future refinery construction needs, and in the energy used in the transportation of crude oil and gasoline.

The crude oil savings obtained with the assumptions outlined above will be offset to a minor degree by the crude oil losses involved in producing 91 O.N. unleaded gasoline which were described in Section 1b.

In this example the net crude oil savings are as follows:

NET CRUDE OIL SAVINGS

[Barrels per day]

	1975	1976	1980	1988
A—With 94 O.N. leaded gasoline	None	None	130,000	280,000
B—With 98 O.N. leaded gasoline	None	25,000	440,000	920,000

No savings would be possible in 1975 because the engines could not be modified that soon. In 1976 the potential saving at 94 O.N. is offset by the loss in producing the 91 octane unleaded gasoline used as the basis of comparison.

From this example, the large crude oil savings obtainable from the use of high octane leaded gasoline are readily apparent. This is in fact similar to the European situation where with scarce and expensive energy over 70% of the cars have been designed for 98 O.N. gasoline for many years. To realize the highest savings, current lead levels (2.5 gm/gal) have been assumed. If air quality standards for lead particulates are established, the application of devices to remove lead from vehicle exhaust may be required to meet them. Several companies have reported very marked progress in the development of these devices, and we believe they are feasible for 80% removal of lead particulates from exhaust.

During the November 5 discussion, Mr. Cole said that increasing compression ratio would increase emissions of hydrocarbons and oxides of nitrogen. We find this to be misleading. The published literature[6] clearly indicates that compression ratio has no effect on the mass emissions of hydrocarbons and oxides of nitrogen; however, the concentrations of hydrocarbons and oxides of nitrogen do increase with compression ratio. This latter effect is offset by the smaller mass of the emissions at higher compression ratio.

2. PRODUCTION OF DESULFURIZED UNLEADED GASOLINE

a. Immediate availability

Both Administrator Train of the Environmental Protection Agency and Mr. E. N. Cole have suggested to the Committee that low sulfur gasoline could be made available in quantities sufficient to meet demands for one or two years. In view of this availability, they both suggested that use of such gasoline would provide a safeguard against the potential harm of sulfuric acid mists from catalytic converters until such time as the problem could be fully evaluated and appropriate action taken.

As explained below enough low sulfur gasoline (0.01% S maximum) can probably be provided to meet the expected demand for unleaded gasoline for more than one year but less than two years. However, as Mr. Clewell stated in his testimony, this proposal is unworkable.

If the decision to build gasoline desulfurization capacity is delayed until after catalytic converters are in use, the demand for unleaded gasoline will exceed the availability of low sulfur gasoline before new desulfurization facilities can be built, as three to four years would be required for construction.

If the suggestion made by Mr. Train and Mr. Cole were followed, and a decision were made at a later date to install gasoline desulfurization facilities, the supplies of low sulfur unleaded gasoline would have to be supplemented with normal sulfur content unleaded gasoline before the end of 1976. By 1978 more of the unleaded gasoline would be of normal sulfur content than of low sulfur content. This would represent a worse sulfate emission problem than potentially exists for 1975.

On the other hand if a decision were made to discontinue catalysts after a trial period, the oil industry would be obligated to supply a declining volume of a special unleaded gasoline for catalyst equipped cars for a least ten years. This would involve expensive and wasteful procedures.

Thus proceeding with the use of catalytic converters and unleaded gasolines without a full understanding of the significance of the sulfuric acid emissions could lead to serious problems some years later.

The estimate of unleaded gasoline consumption used in drawing the above conclusions are as follows:

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[6] "Combustion Chamber Surface Area, A Key to Exhaust Emissions," C. E. Scheffler, SAE Transactions, Vol. 75 (1967).

"Effects of Charge Dilution on Nitric Oxide Emission from a Single Cylinder Engine," V. D. Benson and R. F. Stebar, SAE Paper 710008, January, 1971.

"Effects of Compression Ratio Changes on Exhaust Emissions," A. E. Felt and S. R. Krause, SAE Paper 710831, October, 1971.

"Effect of Compression Ratio, Mixture Strength, Spark Timing, and Coolant Temperature upon Exhaust Emissions and Power," R. C. Lee, SAE Paper 710332, October, 1971.

"Compression Ratio, Emissions, Octanes, and Fuel Economy—An Experimental Study," P. E. Oberdorfer, API Mid-Year Meeting, May 1972.

	Prcent of total gasoline
1975	14
1976	25
1977	35
1978	43
1979	50
1980	56

(The basis for this estimate is given in Section 1–b.)

The refinery gasoline components used to blend finished gasolines contain varying amounts of sulfur. They also have significant variations in octane characteristics and volatility. To provide finished gasolines with properties that will give good car performance, careful blends of the components are required. While producing normal gasolines suitable for the 1974 and earlier cars, our experience indicates that only about 20% of the total gasoline could be consistently produced from existing facilities which would be suitable for use in 1975 and later model cars and have a sulfur content of 0.01% maximum. During the discussion period following Mr. Clewell's testimony, Mr. Graven of Mobil advised the Committee that up to 25% of low sulfur (0.01%) unleaded gasoline could be produced with existing facilities. A more careful review of the problems involved indicates that 20% is a better estimate. (There would, of course, be differences between individual refineries with some being able to produce more and some less than 20%.) In order to produce even 20% of unleaded gasoline with 0.01% sulfur content, the sulfur content of the remaining gasoline would increase, and in some cases would exceed State and Federal specifications.

If an unleaded gasoline sulfur content of less than 0.01% were required, the volume which could be produced immediately would be sharply reduced. In fact, we doubt that the industry, either now or in the future, could meet a gasoline sulfur specification of less than 0.005%.

b. Interference with refinery construction

As noted in Mr. Clewell's testimony the construction of gasoline desulfurization facilities will interfere with the construction of new refining facilities, as skilled manpower and capacity to manufacture specialized equipment will be limiting factors.[6] Therefore, a choice between these two will have to be made. The extent of conflict will be in proportion to the investments involved. Over a ten-year period, these would be $2.5 billion for facilities to desulfurize unleaded gasoline to 0.01% sulfur, and $30 billion for refineries of about 10% interference In the early years, a surge in desulfurization facilities would be needed; thus, the interference would probably be about 20% then.

Another way of expressing this conflict is that construction of gasoline desulfurization facilities will require skilled manpower, shop facilities, and capital investments which could alternately produce about 1,000,000 Bbls/day of refining capacity. This is equivalent to about 7% of the present U.S. refining capacity of 14,000,000 Bbls/day.

3. CURRENT AND FUTURE GASOLINE DEMANDS

During the discussion, several questions were raised by Senators Randolph and Muskie relating to current gasoline demand and past and future gasoline growth rates. The following table contains the information requested:

Year	U.S. gasoline demand (barrels per day)	Annual average growth rate (percent)
1964 actual	4,403,000	4.
1972 actual	6,377,000	
1973 estimated	6,708,000	2.7
1975 forecast	6,950,000	
1976 forecast	7,200,000	
1980 forecast	8,200,000	
1983 forecast	8,800,000	
1985 forecast	9,200,000	

[6] These shortages are discussed in more detail in the paper entitled "The Challenge of Resolving the Energy Shortage" by K. M. Elliott, which was submitted for the record on November 5, 1973.

In view of the uncertainties growing out of the Middle East crises, no reasonably accurate forecast of future gasoline availability or demand could be made. Yet we believed the Committee needed and wanted some quantitative estimate of investment requirements and crude oil penalties associated with the desulfurization of gasoline. For this purpose, we chose to use the published industry forecast giving the lowest future gasoline demand. This forecast was published in December 1971 by the National Petroleum Council as part of their initial appraisal of the outlook for future U.S. energy supply and demand. This forecast contained specific estimates for only 1975, 1980, and 1985. The values given above for 1976 and 1983 were obtained by interpolation. As noted in the table above, this NPC forecast contemplates a sizeable reduction in the historical rate of growth of gasoline demand.

The historical growth rate is based on an eight-year period (1964–1972) instead of the ten-year period requested, as this is the longest period available on a consistent basis. The Bureau of Mines changed the basis of their statistics slightly in 1964; thus, earlier data are on a different basis, and of course, actual data for 1973 are not yet available.

4. POTENTIAL USE OF LEADED GASOLINE IN CARS HAVING CATALYTIC DEVICES

With normal gasoline supplies, we believe that some motorists would find ways to use leaded gasoline in cars equipped with catalytic devices. Their incentive would be to have about 2 cents per gallon in the price of gasoline. With a severe shortage of gasoline and/or with gasoline rationing, the incentive could become the usage of one's car. This is a much more important incentive and could lead to a significant amount of improper usage of leaded gasoline in vehicles designed for unleaded gasoline.

Since very few areas will be inspecting vehicles for emissions, and the cars will operate well on leaded gasolines, the improper use is unlikely to be detected. Emission will, of course, be increased by such usage at 1975 models with lead poisoned catalysts will have higher emissions than 1974 models.

Mr. Rogers. Our last witness today would be Mr. Lawrence E. Blanchard, Jr., executive vice president, Ethyl Corp., Richmond, Va.

Mr. Blanchard, we apologize to you for the late hour. We appreciate your tolerance. And the committee welcomes you, and we will be glad to receive your statement.

I believe you will be accompanied by Mr. Robert Butler, director of environmental affairs, Petroleum Chemical Division, Du Pont Corp., Wilmington, Del.

We welcome you to the committee.

STATEMENTS OF LAWRENCE E. BLANCHARD, JR., EXECUTIVE VICE PRESIDENT, ETHYL CORP.; AND ROBERT C. BUTLER, MANAGER, ENVIRONMENTAL AFFAIRS, PETROLEUM PRODUCTS DIVISION, E. I. du PONT de NEMOURS & CO.; ACCOMPANIED BY HOWARD E. HESSELBERG, VICE PRESIDENT, AIR CONSERVATION PROGRAM, ETHYL CORP.

Mr. Blanchard. Mr. Chairman, I am Lawrence E. Blanchard, Jr., executive vice president of Ethyl Corp. and I have with me Howard E. Hesselberg, vice president in charge of our air conservation program.

Mr. Rogers. Mr. Hesselberg, we welcome you.

Mr. Blanchard. Mr. Butler from Du Pont is just an interloper as far as I am concerned, we let him sit here only by suffrance. [Laughter.]

Mr. Rogers. We welcome you all.

Mr. Blanchard. I am here in support of H.R. 11475 to freeze the 1974 automotive emission standards because they can be met without the use of a catalyst which would require the availability of lead-free gasoline in practically every station in the United States. While a great national debate is going on over that issue, EPA last week issued its rules on the phase-down of lead in all gasoline. In that connection, EPA has now devised a formula—which you have heard about today—under which the oil industry would be forced to reduce the total lead used about the same amount, regardless of whether the catalytic approach is adopted or not. And, therefore, we also urge you to postpone that proposed phase-down for at least 2 years, for the reasons which I will refer to.

We think the combination of these two events—the immediate production of a lead-free grade of gasoline for a catalytic car and the scale-down of lead used in all gasoline—will result in a drastic fuel penalty for the Nation.

EPA dismisses all that by simply determining that there will be essentially no energy penalty. We resent that typical, simplistic approach by EPA.

My company is one of the major manufacturers of tetraethyl lead and we have been under attack since the start of the environmental decade, as most of you gentleman have heard me on this subject before. The last time I testified before you was almost 4 years ago, just a few days before America's first Earth Day. For the past 4 years. I have continued to try to tell America—in legislative hearings, press briefings and on national TV—of the many advantages of leaded gasoline that have been recognized for more than 50 years now. Perhaps the greatest advantage that has long been recognized throughout the world is that lead has saved about 6 percent of all of our crude oil and this amounts to saving an amount each year equal to at least two-thirds of all the oil produced in California each year. And if any of you think that that is inconsistent with all of the numbers you have been hearing today, when I get through, so help me I believe I can explain it.

But the trouble I have had, for the past 4 years, was that few knew what crude oil was and even fewer cared. Conservation is the father of ecology, but the world forgot for awhile the importance of conserving energy. No one, in or out of industry, has ever questioned the desirability of absolutely perfect clean and clear air and water. The only question that has ever been raised is whether the world had enough resources to achieve such perfection.

The severe limitations on our available energy have suddenly come into clear focus. Admittedly, partly because of reasons over which we had no control, but whatever the causes may have been, it now seems clear to everyone that we do not have enough energy to go around. Ironically, the day after the first weekend when gasoline sales are halted, we journey to Washington to debate whether or not America will take the next air purification step or whether we will hold where we are until we can see how many cars we can run with the gasoline that is left.

I personally think we are rearranging the chairs on the deck of the Titanic. I sincerely believe that whatever good or bad decisions we may have made in the past, America will never forget or forgive our not doing everything humanly possible to conserve every single gallon of oil and pound of coal to help us continue to be the great

Nation that we in the boondocks still think we are. If we run out of oil, as you have just heard Mr. Gammergard predict that we are going to, we are going to have terrible problems, environmental included.

Just a trifling example will be the millions of homes having to burn wood or anything else they can get their hands on in fireplaces across the country. I do not think that anyone has yet weighed the micrograms of whatever will be back in our air from that source. And I suppose I put that in yesterday because of just having lit two fires in my fireplace in Richmond, Va., and created a neighborhood disturbance. You never saw so many people lined up in front of the house yesterday.

As for leaded gasoline itself, despite any doom-mongers you may hear from today, or the next 3 days, and try as hard as the EPA has tried for the past 4 years, and despite all the millions of dollars they have spent measuring everything and everybody they can find, no one in the 50 years since tetraethyl lead was invented has ever been able to come forward with even one instance in which the health of any child or adult has been harmed from lead emitted from automobiles. I am attaching to this statement, a copy of a letter from Dr. Paul B. Hammond to the editor of Interface, a scientific environmental magazine, in its November issue [see p. 101] which has just come to my attention, unfortunately today. Dr. Hammond was the chairman of the National Academy of Science committee that exhaustively studied lead in the environment in 1972 for EPA. I submit it supports everything we have said for 4 years.

We can argue all day—when I wrote that, I guess I ought to say we have argued all day—as to exactly what percentage of our crude oil is wasted by reducing lead in gasoline. We think a fair consensus of experts in the field is that even this final reduction just announced by the EPA will waste, on top of the waste from lead-free fuel for a catalyst, at least 1 percent of our crude oil which is more than 100,000 barrels a day, over 4 million gallons, or at least 50 million barrels a year. And again, parenthetically, I do not think there is anything inconsistent there with the numbers we have been hearing.

England announced, just last week, its postponement of a first small lead cut which they had scheduled—which they estimate will save 300,000 tons of fuel, is the way they state it, which works out to be about 1½ percent of their fuel.

But actully this is just a trifle, as you have heard, compared to what is at stake in your decision on a catalyst. As everyone has now heard for the past 4 years, the catalyst will require nonleaded gasoline, but no other country in the world is trying to, at times like this, to switch to that much lead-free gas. It is going to take a huge amount of gasoline just to fill up the new lines and tanks 7 months from yesterday.

The decision by Mr. Cole of General Motors in 1970 to reduce octane requirements and compression ratios, on the theory that we needed to start getting ready for his catalyst in 1974, has needlessly reduced the efficiency of American automobiles over the past 3 years and has resulted in literally wasting more crude oil than America can save by all of the restrictions proposed so far. This crude oil waste was started by Detroit 3 years early to get us used to wasting gasoline before the catalyst arrived, so they could then claim that the catalysts were saving it. To have Mr. Cole now claim that his catalyst will save 13 percent of our gas, is absurd. Perhaps he is basing this claim on America demanding smaller cars, which incidentally is what I understand this sales-weighted average amounts to, it just reflects that he is going to sell more little cars than he used to. But if he is basing it on that, to think that General Motors claims the credit for that shift, must make our friends overseas even madder than it does me. That has nothing to do with environmental controls, as distinguished from you and me deciding that we want to buy a small car. I am attaching to my statement a copy of the Wall Street Journal editorial of this November 30 [see p. 102], which I think makes this identical point and states it soundly.

But even in Los Angeles, where all of this began, the Air Pollution Control District does not endorse the use of catalysts, and the State of California is urging EPA to postpone the regulations calling for lead-free gas in order to conserve energy.

In conclusion, we plead with you to weigh so very carefully the priorities of America. Leaded gasoline can save every year at least two-thirds of all the oil produced in the State of California. We urge you not to set an emission standard that would require the catalytic approach which in turn requires the elimination of leaded gasoline, and we urge you to postpone any scale-down of lead during this energy crisis.

[The letter to the editor and the Wall Street Journal editorial referred to follows:]

LETTERS TO THE EDITOR

[Interface magazine, November]

Dear Sir: I am responding to your request for opinions as to the validity of an EDF statement concerning the hazards of lead emitted into the atmosphere with auto exhaust. The statement I refer to reads as follows: "Lead released into the atmosphere damages the health of many Americans. Cars burning leaded gasoline cause 90% of this pollution."

The first statement is not known to be true and the second is not strictly correct, although it is probably close to the truth.

I feel obliged to comment on these statements because their dissemination does an injustice to the American people. The people are entitled to an accurate representation of the consequences of pollution since it is they, not the EDF, that must pay the cost of controls.

There is no sound evidence that auto exhaust lead "damages the health of many Americans". The most most common misconception among most people concerns the distinction between the presence of a pollutant in the body and the presence of it in concentrations sufficiently high to produce damage to health. Too much of anything in the body is toxic. Too much salt causes damage to health. Too much antibiotic given in the treatment of bacterial diseases causes damage to health. One could expand on that theme *ad infinitum*. There is, however, one difference which must be recognized. In proper doses and under appropriate circumstances both salt and antibiotics are beneficial, whereas there is no known benefit from any dose of lead. Yet lead is present in all biological systems, including primitive human societies far removed from auto exhaust or other man-generated sources. It is not a question of whether or not people have lead. They all do. It is rather a question of how much lead they have and how much is harmful. So far as adults are concerned, the general population is exposed to far less lead than are workers in battery factories and lead smelters who remain in good health in spite of their high exposure as compared to the general public. This is not to say that men in the lead industries never get intoxicated. On occasions they do, but only at exposure levels well above the exposure level for the general public.

This also is not to say that there has been no concern in the scientific community pertaining to the consequences of general atmospheric lead for human health. Far from it. There have been literally thousands of studies conducted relating to the consequences of lead exposure. And these studies are being continued. This vast literature was recently summarized and evaluated by a panel of experts under the sponsorship of the National Academy of Sciences. I was privileged to be the chairman of that panel, and I can attest to the diligence, competence, and objectivity with which the study was conducted. The major concern expressed by the panel was regarding the possibility that very young children in areas of high vehicular traffic density might mouth or eat sufficient lead-bearing street dust and soil to pose a threat to their health. Lead poisoning indeed is an all-too-frequent occurrence among children of the inner cities. But the source of lead identified in the vast majority of cases has been lead-based paints which these children chew and swallow. It is at present uncertain to what extent soil and street dust contaminated with lead from auto exhaust fall-out contributes to the problem. But what little evidence has been adduced so far suggests that this is probably not a significant source. Further evidence is needed on this point. Current research ongoing in a number of laboratories around the country will no doubt soon provide more conclusive evidence as to the role of auto exhaust fall-out as a source of lead in young children.

The second sentence in the EDF statement relates to the contribution of auto exhaust emissions to lead pollution. No one really knows what the contribution of auto exhaust is. It is true that approximately 98% of *inventoried* emissions are attributable to the combustion of gasoline. But it is not to be concluded from this that 90% of the total lead vented into the atmosphere originates from auto exhaust. For one thing, a substantial fraction of lead from gasoline combustion is trapped in the engine. For another, there is a difference between inventoried emissions and total emissions. Thus, while we know how much tetraethyl lead is sold annually and is probably combusted, we have no way of estimating the amount of lead vented into the atmosphere from certain other sources such as the burning of lead-containing waste in city dumps. The combustion of leaded gasoline may well account for most of the man-generated atmospheric lead, but to place a number on the contribution made is unwarranted.

Paul B. Hammond, D.V.M.
Dept. of Environmental Health
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[Editorial from the Wall Street Journal, Nov. 30, 1973]

Decision on Catalysts

Sold on the idea that catalytic converters will not only clean automobile emissions but also yield a 13% improvement in gas mileage, the Senate Public Works Committee this week decided to give its blessing to the devices. Unless the House decides in the next few days to dispute this decision, most cars manufactured next summer will be so equipped, adding $150 to the price of each auto and, more importantly, committing the nation to them for years to come.

The committee did vote 11 to 3 to delay for one year a further tightening of the auto-emission standards beyond requirements for the 1975 models. But this was a trivial gesture when compared to the committee's embrace of the catalysts. General Motors Corp., the chief catalyst enthusiast, has indicated it will equip almost all of its 1975 models with catalysts; Ford and Chrysler will probably equip the majority of their cars with them. Once embarked on this course, which involves considerable investment by the auto and petroleum industry, it's likely the nation will be denied more promising technology into the next decade.

What finally seems to have swung the committee away from the course we recommended—a freeze of current standards until the National Academy of Sciences completes its study of them—is that 13% mileage benefit claimed for the catalyst by General Motors. If it were indeed true that GM's 1975 models will get car-for-car 13% better mileage than its 1974 models the catalyst would at least have some benefit to set against its other drawbacks. If the nation goes to gas rationing, there might even be a public stampede to fit the gas savers to current models; they'd pay for themselves in a year or so.

But this isn't quite what GM is saying. First, the 13% saving only applies to city driving; it's much less on the highway. Secondly, the 13% saving was calculated on a sales-weighted basis. In other words, all of the 1975 models GM produces will show a 13% mileage benefit over all the 1974 cars it is selling when those two auto populations are compared in stop-and-go city driving. Clearly, a great deal of the 13% is explained not by catalysts but by the fact that GM expects to sell a lot more small cars in 1975 than in 1974. This tells you something, by the way, about the statistics GM used in selling its catalyst position.

It is fairly certain that on a direct car-for-car comparison a 1975 model with a catalyst will have better gas mileage than a 1974 model without one. Ford and Chrysler figure the gain at 3%. This isn't because the catalysts, which are plugged into the exhaust system, make the car run better. But to meet the 1974 emmission standards the car makers have had to untune the engines from their peak efficiencies; adding the catalyst permits them to recapture a bit of that lost efficiency. That 3% gain will be more than wiped out, however, by the requirement that catalysts use only unleaded gas; to refine gasoline into higher octanes without using lead means a 4% or 5% gasoline loss in the refining process.

Unfortunately, it will cost the petroleum industry several billion dollars over the next decade to accommodate the catalysts, and we do not even know if the emission standards they are designed to meet are valid. The National Academy is now spending $500,000 to find that out. Worse, the catalyst course will inevitably mean delays in development of the stratified-charge engine, which promises real fuel savings and clean emissions. We are least hope that one rumor we hear proves unfounded and that the Senate committee will have the decency to refrain from calling its catalyst decision "The Fuel Economy Bill."

Mr. Blanchard. Mr. Chairman, Mr. Hasselberg and I will be glad to respond to questions, or if you would prefer, perhaps you would rather have Mr. Butler make his statement and then all three of us will be available.

Mr. Rogers. Yes; Mr. Butler, why do you not make your statement.

STATEMENT OF ROBERT C. BUTLER

Mr. Butler. Thank you, Mr. Chairman, members of the committee, my name is Robert C. Butler, I am manager of environmental affairs for the petroleum chemicals division of Du Pont. I apologize that I do not have a written statement. I learned only early this afternoon that I might have an opportunity to make a few comments to the committee.

I would like to start by endorsing the comments presented for API by Mr. Gammelgard. We concur in the points they made. I would like to describe, just briefly, some work which Du Pont has been doing for a number of months on the relationship between air quality and automotive emission standards.

One of the problems, we believe, is that the automotive emission standards are not soundly related to the air quality standards which they are intended to achieve.

Mr. Rogers. Excuse me, what is the lead standard?

Mr. Butler. Sir, there is no Federal lead standard at the moment.

Mr. Rogers. None related to lead?

Mr. Butler. That is correct, not on a Federal basis.

Mr. Rogers. I thought that was correct.

Mr. Carter. Mr. Chairman?

Mr. Rogers. Yes.

Mr. Carter. If you would yield, on that basis, I asked that question today and they mentioned the figure of 2 micrograms per cubic meter, while at the same time they stated that toxic level in the blood is 40 micrograms per cubic meter—I believe I am correct in that. These figures are grossly in error.

Mr. Rogers. Yes; but I think there is no published standard.

Mr. Carter. You are correct. These figures are incorrect.

Mr. Rogers. Yes.

Mr. BUTLER. Sir, in this case, I was referring to the standards for gaseous pollutants from automobiles, hydrocarbons, carbon monoxide, and nitrogen oxides, rather than specifically to lead.

Mr. ROGERS. Sure.

Mr. BUTLER. Our studies have shown for example that, the 1974 emission standards for carbon monoxide are adequate to insure that the air quality standard for that pollutant can be attained. We have somewhat less information on hydrocarbons and nitrogen oxides, but preliminary indications are that the mandated emission standards for those two pollutants are also more severe than is necessary. Earlier this afternoon, I believe EPA indicated that that was also true for the nitrogen oxides.

We have looked more carefully at carbon monoxide because there is a great deal of data available on that pollutant. I would like to emphasize that we are not proposing any compromise or any change in the health-related air quality standards no compromise with clean air or air quality. Rather, our studies indicate that the level of air quality, which is presently established as the air quality standard, can be obtained with a lesser degree of control than is now mandated by the Clean Air Act.

If air quality goals can be achieved with a lesser degree of control, then the fuel economy penalties that have been discussed here this afternoon, can be avoided. If the standards are frozen at the 1974 levels as has been proposed, the use of catalytic devices and the problems associated with them can be avoided.

More stringent emission standards, in general, mean a greater loss in fuel economy. The amount of that loss is open to debate, but certainly the direction is not. Claims of improved fuel economy, with catalytic systems, need to be related to the standards which are achieved with those systems.

Claims of improved fuel economy are often related to 1973 models, the fuel economy of which is already poor.

Let me explain some of the results that we have achieved in our efforts to develop a more precise relationship between automotive emissions and air quality. We found in examining air quality trends for a 10-year period, that the carbon monoxide levels in major urban areas in the country has been trending downward. This is coincident with a corresponding decrease in the carbon monoxide emissions from automobiles.

We find the observer air quality standard for carbon monoxide, can be met with tailpipe emission standards considerably higher than the presently mandated 3.4 grams per mile. Our analysis would indicate that a value of 30 grams per mile would be adequate to achieve the carbon monoxide air quality standard in Chicago the city that was used as the basis for the standard. We find that the rollback calculations that are being used by EPA to derive emission standards and are now being used to predict future carbon monoxide levels, do not correlate well with what is actually happening in the atmosphere.

Analyzing air quality trends, provides an excellent means of establishing a relationship between tailpipe emissions and air quality. As you are aware, the National Academy of Science is conducting, a study to determine the validity of the air quality and emission standards as mandated by the Clean Air Act Amendments of 1970. We urge that the emission standards be retained at the 1974 level which would not require a catalyst until the results of the National Academy of Science study are available.

We believe that the environmenal risks of keeping the stringent 1973–74 standards in effect, for an additional year or two are small compared to the long-range consequences of imposing unnecessarily restrictive standards. Thank you, Mr. Chairman, I will also be happy to answer any questions you might have.

Mr. ROGERS. Thank you, Mr. Butler. Mr. Satterfield?

Mr. SATTERFIELD. Thank you, Mr. Chairman.

Mr. Butler, do you know when the National Academy of Science studies that you mentioned are expected to be published?

Mr. BUTLER. The final report of that study, sir, is due in August 1974.

Mr. SATTERFIELD. So that would be at a time when the 1975 models are actually coming on the market?

Mr. BUTLER. That is correct.

Mr. SATTERFIELD. Are you familiar with any study that is going on with respect to emissions from catalytic devices such as sulfur oxides, sulfuric acid mist, and the like?

Mr. BUTLER. We have done no work in that area, sir, but I am familiar with the work that others have done.

Mr. SATTERFIELD. Some studies are still in progress, are they not?

Mr. BUTLER. Yes, they are, including one by the Environmental Protection Agency.

Mr. SATTERFIELD. Is there any alternative way to keep lead out of the air, other than taking it out of the gasoline, in terms of burning leaded gasoline in an automobile?

Mr. BUTLER. Yes. sir, it has been Du Pont's position that what we are really concerned about, if there is need for concern at all, is lead emitted from the tailpipe of the automobile, not what is in the gasoline. There are lead-trapping systems which are quite effective in removing the lead before it is emitted into the atmosphere.

Our work has shown that the overall trapping efficiency is some 90 percent. In other words, only 10 percent of the lead in the gasoline would be emitted into the atmosphere. The allegation has been made that such traps are not as effective on the small particles that would remain airborne for some period of time. We find in our test work that they are some 70 to 75 percent effective even on the submicron sized particles.

Mr. SATTERFIELD. Are you familiar with any studies which have been submitted to EPA that woul tend to substantiate your viewpoint on this?

Mr. BUTLER. Sir, our test work has been made available to EPA as well as tests which they have had conducted for them by Dow Chemical Co., in Michigan, and others. I know that test work, done by our competitors sitting next to me here, and others, has also been made available to EPA.

Mr. SATTERFIELD. I would like to ask Mr. Blanchard that question. I know that you have been involved, if I read the newspapers correctly, in a case in which you were able to obtain certain papers that had been filed with EPA, is that correct?

Mr. BLANCHARD. Yes; we brought a Freedom of Information Act suit that has received some considerable publicity because it happened to be going on at the same time of another Freedom of Information matter. And as a result, we have been able to finally get EPA to give us, I think the latest count was eight feet of documents, which we have been finding of considerable interest in wherever we go from here. This, however, does not seem to have convinced them.

Mr. SATTERFIELD. Have you found that these documents would indicate that lead is not the health hazard that might have been indicated earlier?

Mr. BLANCHARD. Well, as I think you gentlemen know, all you have to do is push that button on me, and you better watch the clock, because I feel——

Mr. SATTERFIELD. Maybe I had better rephrase the question.

Mr. BLANCHARD. And in all seriousness, Mr. Satterfield, that is why we have attached this letter which I have attached to my statement which I think is one of the most impressive summaries we have seen. One thing that has been so difficult about the lead issue is that it is so complicated. I think that even our opponent will agree with that, that it is a very complex issue. This is something that has been presented in a relatively short amount of space, and it is done—as I say, by the man who was the Chairman of the National Academy of Science's study that was done at the request of the EPA. The only trouble was that EPA did not like the outcome so they started over to do another study which came to an opposite conclusion.

But, this is the summary of it by Dr. Hammond, himself, which I think speaks on the subject certainly with more credibility than I have.

Mr. SATTERFIELD. Let me ask you this. Are you familiar with a statement made by John Quarles, Deputy Administrator of the Environmental Protection Agency, on November 28 when he announced a phasedown plan?

Mr. BLANCHARD. Yes. I have reviewed the transcript of it; I was not at the press conference.

Mr. SATTERFIELD. I would like to invite your attention to some things he said, although he pointed out that the matter was complex, as you indicated, and suggested that there are areas that need to be explored in terms of lead paint, lead in dust, lead particles in the air, and the like. He then made this statement:

> First I would like to point out a few key points on which our current air knowledge is incomplete. Research has not documented without reasonable doubt the levels of airborne lead in ambient air at which health effects in persons would be caused.
>
> For this reason, we do not have a basis on which ambient air quality standards for lead could properly be established at this time.
>
> We also have not been able to determine, with any high degree of precision, the specific sources of lead exposure in cases where persons have developed excessive blood-lead levels, although of course lead in peeling paint has been identified as the primary source of lead poisoning among urban children.
>
> Finally, we have only limited knowledge on the extent to which significant adverse health effects may result from lower levels of exposure below the excessive blood-lead levels, causing severe clinical injury.

Would this square with what you have been able to ascertain through your action in court?

Mr. BLANCHARD. Yes, and we think this was an admittedly unusually candid statement for EPA to make at the time of issuing their regulations. Obviously, what we do not understand is, after having said that, what the basis is for restricting them. They admit that they do not have the necessary information to come out with the ambient standards which have been put out on many other items in the atmosphere—sulfur, as an example. Congress is now considering, in view of the energy crisis, that we are going to have to waive some of these standards.

Here, they admit they do not have sufficient information to establish an ambient air standard. And under those circumstances it certainly seems clear to me that it is appropriate, when the question is whether we are going to have any gasoline to run any cars, is to consider the ways that will extend our gasoline usage, certainly during the energy crisis, despite this determination.

Mr. SATTERFIELD. I must say I found this puzzling also when I read it, and I would like to ask any one of you gentlemen at the table whether or not there are any additives which could replace lead in gasoline to produce an analogous performance efficiency in gasoline?

Mr. BLANCHARD. I would like to answer that, Mr. Satterfield, because the EPA goes out of its way to kick us an extra lick when we are down.

It is pretty well known that Ethyl for a long time has worked on a manganese additive, which we have never contended was remotely as effective as lead—certainly not in the same ballpark as to effectiveness. But it is something that conceivably could add an extra octane or two, compared to three to eight, or some such thing, that lead can add. It is something that we have been doing a great deal of research and testing on, and have been working with them on. They go out of their way in these documents to say that they are not satisfied that that meets their health standards, and obviously from their attitude it will make quite a few years to convince them, presumably, whatever it takes to convince them that this additive would not be hazardous. But that is the only one that I know of that anyone has remotely suggested might conceivably be a substitute for lead, except the one that I have talked about before your committee so many times before, is that the only substitute for lead is aeromatic hydrocarbons, that if you take the lead out, and if you are going to keep roughly the same octane number, then what you have to do is increase the aeromatics that are added to gasoline, which are themselves hydrocarbons, as you know, and which we think raise infinitely more serious health questions than have ever been suggested about lead. But that is another subject, and I am sure it will take longer than you gentlemen have tonight, and you have heard me on it before.

Mr. SATTERFIELD. Thank you, Mr. Blanchard.

Thank you, Mr. Chairman.

Mr. ROGERS. Dr. Carter?

Mr. CARTER. Thank you, Mr. Chairman.

Taking lead out of gasoline and making an unleaded gasoline would cost us how many barrels of gasoline per year?

I believe you said as much as was produced in the State of California.

Mr. BLANCHARD. Well, I say—to be conservative, I say two-thirds of the amount. I think it is probably as much, but I want to be cautious.

Mr. Carter, that is an extremely difficult thing to explain simply, as you have heard these people at this table wrestling with it today. To answer the question, I think you have to go at it backwards. If you will permit me one moment, and that is that you have to take my word for the moment that the, generally speaking, the maximum efficient level to operate an automobile to get the most miles per gallon is at a given compression ratio, which—I will not try to argue precisely for example, let us just pick something simple and say a 10-to-1 compression ratio, which happens to be—and it is a pure happenstance of physics—that happens to require an octane number of about 100, roughly 100 octane will operate a given engine at roughly maximum efficiency.

Lead adds octane to any given level of gasoline that you have refined. It used to refine it up to, oh, Phillips 66 way back. Later gasoline got up to 70 octane. Later it got up to 90, and eventually, coming after World War II, when we operated airplanes on 100 octane, 100 octane became a standard. 100 octane is maximum, roughly, efficiency, to get you this 10-to-1 compression ratio.

Now, if you want to take lead out of gasoline and go from today's pool—whatever you want to say it is. You heard today that average pool is probably 88½. To get from pool today to 100 octane, which will permit you to operate engines at maximum efficiency, will require to go through that refining process an additional 6 percent more crude oil, give or take a half a percent, generally speaking, as described around the world as 6 percent more crude.

Now, you say, okay, but so what? We do not want to do that. We would rather come on down and quit operating in a 10-to-1 compression ratio. We would rather come down and operate at some other compression ratio that we can operate at and not do anything more to the gasoline. We got an 88½ pool right now, do not do anything more to it. Leave it alone.

What compression ratio can operate at then?

Forget exactly what that compression ratio is. I am not smart enough to argue with you as to what it is. It is somewhere I will just say 8 to 1, to make it simple.

Whatever it is to operate at 8 to 1, you will lose between 10 and 12 percent gasoline mileage to come down to that compression ratio, which wastes 5 to 6 percent crude oil, as distinguished from the 10 to 12 percent gasoline since you get a half barrel—a barrel of crude yields about a half a barrel of gasoline.

So you can look at it either way. Lead either permits you to get your octane up to the most efficient compression ratio, or if you want to say, the heck with the compression ratio, we are coming down to whatever our pool gas is, you will lose the same amount of efficiency in your gasoline. Which is why we say lead saves about 6 percent of all of our crude oil. Now, you can take that baby I just described, and slice it half in two, a third in two, or you can cheat like General Motors does.

You can pretend you are satisfying all of the cars with 91, and you are not losing but just a little bit on your compression ratio. Well, I submit that even they have never been able to repeal the law of thermodynamics, and I simply do not believe what they say. I think you are still going to waste 6 percent of your crude oil, or you can waste 12 percent of your gasoline any way you slice it.

Mr. Carter. How much is a microgram?

Mr. Hesselberg. One millionth of a gram, Mr. Carter.

Mr. Carter. One millionth of a gram.

And a cubic meter is how much of an edge?

Mr. Hesselberg. It is about 35 cubic feet.

Mr. Carter. It is 39.36 inches on an edge, is it not?

Mr. Hesselberg. It is about 35 cubic feet.

Mr. CARTER. On an edge, the edge would be 39.36.

Mr. HESSELBERG. Yes; but it comes out to about 35 cubic feet.

Mr. CARTER. And would a pencil point on the face of a cube represent 2 micrograms or not on a cube of that size?

Mr. HESSELBERG. I do not have really any idea of the weight of a dot of a pencil point, Mr. Carter. But it is very, very small, obviously. A millionth of a gram, and considering that there are about 29 grams in an ounce, you are getting down to—putting it in English system terms you are getting down to pretty small weight.

Mr. CARTER. It almost approaches infinity, does it not?

Mr. HESSELBERG. It is very small.

Mr. CARTER. Yes, sir, compared to a cubic meter.

Mr. HESSELBERG. Of air.

Mr. CARTER. Yes, sir.

Mr. HESSELBERG. I think, Mr. Carter, there was a statement made that was originated with the EPA people, and I think they were just misquoting. They were talking about blood lead levels, and quoted 40 micrograms, and inadvertently, I am sure, said per cubic meter of blood. I am sure you are aware that they meant 100 grams of whole blood, and not a cubic meter of blood. It is quite a bit of blood.

Mr. CARTER. It really is.

Mr. HESSELBERG. They were off by a small factor of blood.

Mr. CARTER. Well, I believe they also said of the ambient air that there is not a standard, but, when I asked them that question, they mentioned 2 micrograms per cubic meter.

Mr. HESSELBERG. This is the number that they proposed some time back in an earlier proposal they had proposed, revised and reproposed this lead regulation at a date sometime back. They one time felt that they could justify, and attempted to justify, an ambient air standard of 2 micrograms per cubic meter. This, as they have now admitted, was a rather vain attempt and was pretty thoroughly discredited by the scientific community.

Mr. CARTER. As scientists, how difficult would it be to measure that, or to arrive at, or to find the concentration of 2 micrograms per cubic meter?

Would it be pretty difficult or not?

Mr. HESSELBERG. It requires very specific, detailed, analytical procedures. To do it, you do not measure 1 cubic meter. You determine by the use of pumps and filtration the amount of lead that is in many cubic meters, then you analyze that and equate it to the cubic meter. But it is—yes, a very difficult technique. It is one that is generally, however, used by the scientific fraternity, and they are capable of measuring values in this order with a considerable degree of accuracy.

Mr. CARTER. Thank you, sir.

Mr. ROGERS. I just have a couple of questions. Mr. Butler, I think it would be helpful if you would make available your studies to the committee.

Mr. BUTLER. I would be happy to do that, Mr. Chairman. I have copies with me.

Mr. ROGERS. And I guess you gave us pretty much a summary but if that needs to be amplified, if you would do that and then give us the backup material for our files, it would be helpful.

Mr. BUTLER. I would be pleased to do that.

[Testimony resumes on p. 169.]

[The material referred to follows:]

RELATIONSHIP BETWEEN AUTOMOTIVE EMISSIONS AND AMBIENT AIR QUALITY LEVELS

SUMMARY

Aerometric data collected by the Federal government in the CAMP program for the past ten years has been used to develop and evaluate specific relationships between automotive emissions and ambient air quality levels. This study has been focused mainly on carbon monoxide to date. Verification tests have shown that little confidence can be placed in the prediction of air quality given by either the simple rollback model or the modified rollback approach currently used by EPA.

An improved relationship between automotive emissions and air quality has been developed based on analysis of measured air quality trends. Use of this approach has shown that reduction of automotive vehicle emission rates to an average of 29 grams per mile should result in attainment of the ambient air quality standard for carbon monoxide even in the worst urban areas.

E. I. Du Pont De Nemours & Company
Petroleum Laboratory
Wilmington, Delaware 19898

September 10, 1973

SCOPE OF DU PONT PROGRAM

The objective of the nationwide effort following the passage of the Clean Air Act Amendments of 1970 is to achieve and maintain levels of air quality adequate to safeguard the public health and welfare. Because of the potentially large economic, social, and environmental costs of this effort it is vital that the relationship between the protection of health and welfare and the actual control of specific pollutants be determined as precisely as possible.

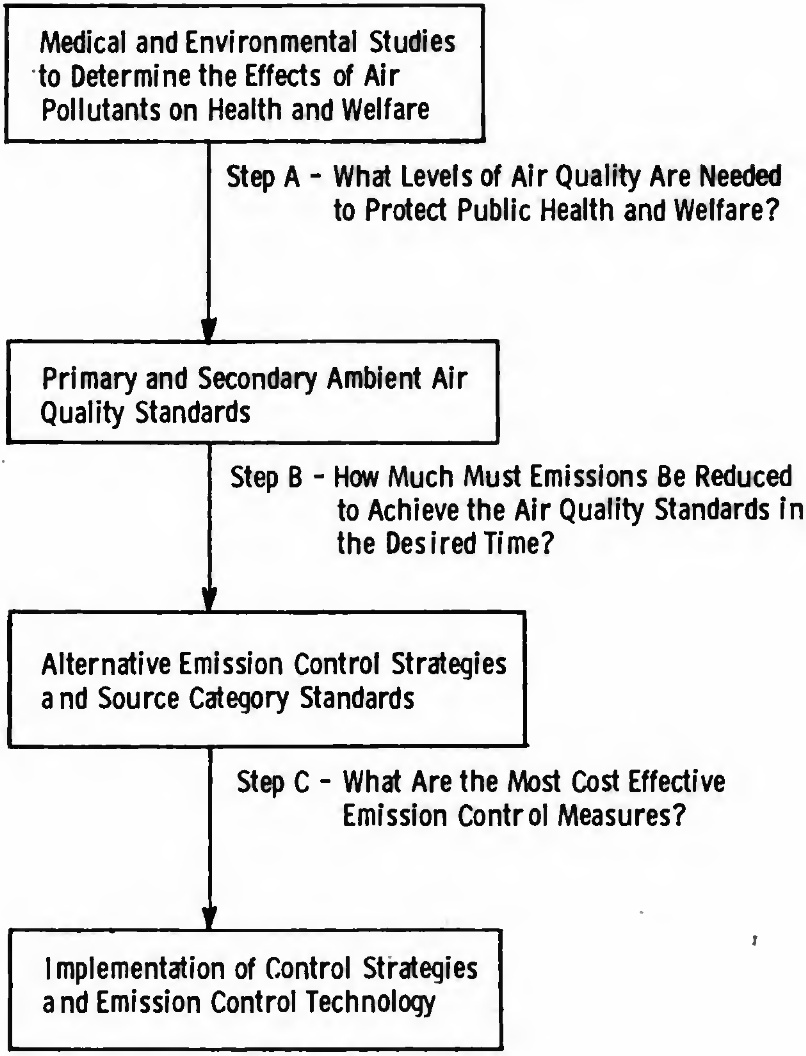
We visualize the process of arriving at the proper course of action to be as shown in Figure 1. Objective studies must be made to determine the effects of pollutants on human health and on welfare which includes the aesthetic qualities of life as well as damage to plants, animals, and inanimate objects of value. Based on these studies, the first judgmental point, Step A, in the process must be considered.

Step A is to answer the question of what levels of air quality are needed to adequately protect public health and welfare. Of necessity this step is not precise because all of the knowledge needed is not and probably will never be available. As a result, factors of safety must be introduced to insure that health and welfare are not jeopardized. The magnitude of the factor of safety is open to debate because of differing judgments as to the adequacy and accuracy of the medical and environmental studies. Also, because a larger factor of safety ultimately requires more stringent, and thus more costly, control measures the question of cost versus benefits to be gained arises. Resolution of these problems inherent in Step A could result in the establishment of primary air quality standards designed to protect public health and secondary air quality standards designed to protect public welfare. Alternatively, a range of air quality standards could be determined which will yield varying degrees of benefit to the public. The ultimate cost of alternative control strategies can be contrasted to the benefits to arrive at an assessment of cost-benefit ratios. In either case, a set of air quality standards can be established to allow continuation of the process of determining the courses of action.

Establishment of air quality standards allows the second judgmental point, Step B, in the process to be considered. Step B is to answer the question of how much emissions need to be reduced to achieve the air quality standards in a given time period. This step, similar to Step A, is also not precise because once again all of the information needed is not available. The most significant gap in our knowledge in this area is the relationship between the amounts of pollutants emitted from various sources and the resultant levels of pollutants in the atmosphere. Various models to predict this relationship have been proposed but, as will be discussed in detail later, they are not adequate. Also needed in

Figure 1

CONTROL OF AIR POLLUTION



Step B are firm data on past and present ambient air levels, emission levels from various sources, the growth rate of the sources, and the degree of control which has been or will be applied to these sources. Not enough data on these points are available either. Again, differing judgments have been made based on the data available to estimate the degree of emission reduction required to achieve the air quality standards. Once the degree of reduction in emissions is estimated, or alternately a range in reduction estimated, alternative strategies to achieve control and appropriate source emission standards can be determined.

The last judgmental step in the overall process is Step C which is to determine the most cost effective of the alternative means to achieve the desired control of emissions. Once again this step is not precise because the costs in terms of economic, social, and environmental factors have not been quantified. This lack of quantification is due in part to inadequate data on the cost of alternate control measures. Again, differing assessments have been made to determine the preferred control measures. Establishment of preferred control measures enables specific emission control strategies and emission control technology to be scheduled for implementation.

Once the final decision on implementation has been made the total costs can be estimated and compared with the benefits to be expected due to the reduction of air pollution. If alternative implementation plans are considered then the cost benefit ratio for the different plans can be used as a guide to choose the best overall means to protect health and welfare. Unfortunately, the uncertainties inherent in Steps A and B make it extremely difficult to arrive at definitive assessments of what degree of emissions control is needed. These uncertainties coupled with the uncertainties in Step C prevent quantitative assessment of the cost effectiveness of various implementation plans and thus the determination of the overall cost benefit ratios.

We at Du Pont looked at this process of determining the proper course of air pollution control with respect to those pollutants associated with automotive emissions. We concluded that the weakest link in the process was Step B because of the lack of an adequate understanding of the relationship between emissions levels from various sources and the resultant atmospheric levels of the pollutants.

Further examination of Step B revealed that it should be easier to arrive at definitive relationships for carbon monoxide than for hydrocarbons or nitrogen oxides. In urban areas automotive traffic is the dominant source of carbon monoxide whereas other sources are major contributors to hydrocarbons and nitrogen oxide emissions. Also, carbon monoxide does not react rapidly in the atmosphere and thus it would be more likely to be directly related to emission rates than hydrocarbons or nitrogen oxides which can undergo atmospheric reactions. Accordingly, we have examined various models to explain the relationship between emission rates and atmospheric levels of carbon monoxide. Once a model can be validated for the simplest of the automotive pollutants it might then be extended to the other pollutants.

The studies we have made on carbon monoxide are summarized in chronological order in the succeeding sections of this report. Details of the studies are covered in the Appendices. The areas of this investigation and the major findings were:

Simple Rollback Model - The simple rollback approach as used in the past was found not to be applicable to the prediction of carbon monoxide trends in major urban areas.

Air Quality Trends - The downward trends of the observed highest levels of carbon monoxide in the CAMP cities were compared with known reductions in vehicle emission rates. The variability in the highest observed levels resulted in poor confidence in future predictions.

Annual Means - A very good relationship was found between the annual mean carbon monoxide levels and the fraction of the time that the air quality standard was exceeded in the CAMP cities. This relationship predicted with a high degree of confidence that an annual mean of 2.3 ppm carbon monoxide would be low enough to allow the air quality standard to be met. Comparison of recent annual mean values to the needed level allowed calculation of the degree of emission reduction required for automobiles. This study indicated that reducing the average automobile emission rate of carbon monoxide to 29 grams per mile would be sufficient to meet the ambient air quality standard.

Modified Rollback - The modified rollback approach currently used by EPA was applied in the CAMP cities to predict levels of carbon monoxide for the past several years. The difference between the predicted and observed carbon monoxide levels was found to be unacceptably large since the prediction error was of the same magnitude as the observed levels.

SIMPLE ROLLBACK MODEL

The use of diffusion models of the urban atmosphere for prediction of ambient air quality appears promising. To date, however, this modeling technique has not been developed to the point where it can be used to establish emission standards. Thus, practical technical estimates of needed emissions reductions have been made on the basis of the so-called "rollback" approach. This approach assumes that the pollutant concentration is proportional to the emission rate of that pollutant in an air basin, with a small correction for the background level of the pollutant.

The "simple" rollback equation is

$$R = \frac{(GF)\,(EAQ) - (AQS)}{(GF)\,(EAQ) - (B)}$$

where
R = fractional emission rate reduction required to achieve the air quality standard
GF = emission growth factor
EAQ = existing air quality
AQS = air quality standard
B = background air quality

The first problem in applying rollback methodology is the validity of assuming direct proportionality between emissions totaled over an air shed, and peak concentrations encountered at specific points in the air shed. If this assumption is true, then it would be justifiable to project future air quality at any point in the region on the basis of the anticipated growth of the entire urban complex. This would also imply that ambient pollutant concentrations at all points within an air shed are directly related.

We made a test of this assumption for Chicago, using data from the EPA CAMP station in the central business district, and from outlying air sampling stations operated by the City of Chicago. Two of these sites are in residential areas, and the other two are near expressways, at distances from 2.5 to 12 miles from the center city CAMP station. The analysis, described in detail in Appendix A, showed that daily average CO concentrations at the five stations were essentially unrelated. Evidently this indicates that ambient atmospheric carbon monoxide air quality data should be related to nearby, not remote, traffic activity. Chicago central business district traffic, rather than metropolitan area traffic, should be considered therefore in attempts to explain air quality measured at the CAMP station.

This analysis points up the second problem in applying rollback, namely proper choice of the growth factor. Cordon traffic counts verify that traffic saturation exists in the Chicago central business district around the CAMP station, as illustrated in Figure 2. It is generally agreed that no significant increase of vehicle use can reasonably be expected in other large urban business districts either. Therefore, it appears that simple rollback cannot be applied to develop projections of air quality in mature urban regions on the basis of anticipated fringe regions growth.

EDITOR'S NOTE: Appendix A may be found in the committee's files.

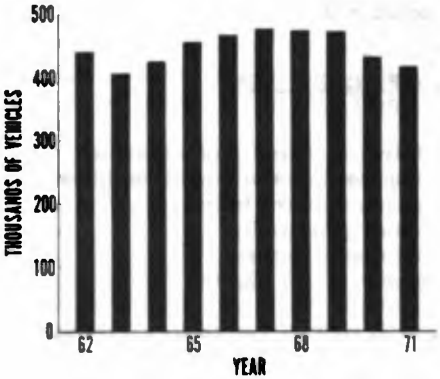


Fig. 2 - Weekday Daytime Traffic in Chicago Central Business District

AIR QUALITY TREND ANALYSIS

An alternative to the simple rollback approach is available which involves analysis of air quality trends. The approach, developed as part of our studies, and described in Appendices A and B, is based on an examination of the aerometric data record for cities with long term measurement bases, to evaluate what discernible air quality changes have accompanied changes in pollutant emissions over the years.

The case of carbon monoxide is mostly directly amenable to analysis because two simplifying assumptions can be made:

- Carbon monoxide in urban areas originates exclusively with motor vehicles.
- The half-life of carbon monoxide in the atmosphere is much longer than the air mass exchange period.

EDITOR'S NOTE: Appendix B may be found in committee's files.

Table I illustrates that there has been a general improving trend in CO air quality over the years.

TABLE I

CAMP CITY AMBIENT CARBON MONOXIDE TRENDS

Year	Percent of Time the 8-Hour Federal CO Standard Was Exceeded					
	Chicago	Denver	Washington	Cincinnati	St. Louis	Philadelphia
1962			11			
1963			20	29		
1964	67		5	20	16	23
1965	92	26	2	2	21	35
1966	71	34	2	3	12	18
1967	40	30	5	6	7	19
1968	18	11	2	6	2	39
1969	38	5	0	-	1	1
1970	24	16	2	-	0	2
1971	14	19	2	1	1	1

Over the same period of time covered by Table I, there also has been a decrease in the average CO emission rate of vehicles on the road. This decrease, illustrated in Figure 3, has resulted from retirement of older, uncontrolled cars, and their replacement with new models, which have met increasingly stringent emission standards.

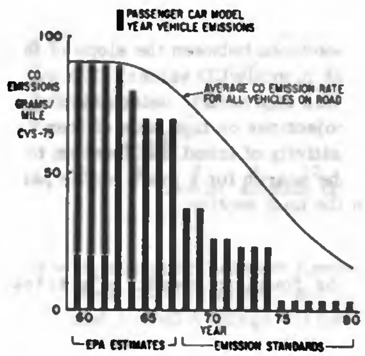


Fig. 3 - Effect of Introduction of CO Emission Controls on Vehicle Population Mean CO Emission Rate

In the preceeding section, it was shown that Chicago central business district traffic is constant. This condition of traffic-saturation is generally accepted as characteristic of mature center city districts, which coincide with the regions of expected maximum CO concentration, and with the locations of CAMP sampling stations. Because traffic can be considered constant, the curve of average CO emission rate shown in Figure 3 can be used as an index of total CO emissions in the vicinity of the air monitoring station. This curve is replotted on Figure 4, which also shows the highest 8 hour nonoverlapping average CO concentration in each month of record for the Chicago CAMP station.

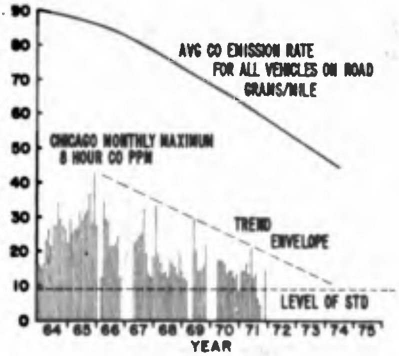


Fig. 4 - Comparison of Vehicle CO Emission Rate and Monthly Maximum CO Values in Chicago

There is a striking correspondence between the slope of the CO emission curve and the trend envelope of peak monthly CO values. However, a comprehensive analysis of the predictive value of this approach to determination of emission standards, given in Appendix C, shows that projections on the basis of trend envelopes are subject to large uncertainty. The sensitivity of trend line location to presence or absence of a few extreme values led us to the search for a more stable parameter describing air quality, which is discussed in the next section.

EDITOR'S NOTE: Appendix C may be found in committee's files.

MEAN AND EXTREME VALUES OF AMBIENT POLLUTANT CONCENTRATION AS MEASURES OF AIR QUALITY

It will be recalled that the air quality standards for CO, hydrocarbons, and photochemical oxidant are specified as concentration levels, over given averaging times, not to be exceeded more than once a year. Therefore, demonstration that the standards are being achieved, or evaluation of progress toward achievement of the standards, requires a high degree of confidence that the air quality measurements used to estimate the frequency distribution of pollutant concentrations are representative. Unless truly continuous measurements are made, the confidence of an estimate of the frequency of occurrence of a rare event, such as is implied by the air quality standard, is degraded. However, if it could be shown that a definite relationship holds between the number of violations of the concentration level of the standard, and a less sensitive property of the distribution, such as a long period mean, then that mean could be used to determine appropriate emission reductions to meet the air quality standards.

By analysis of an aggregate of 51 years of data from the six CAMP cities, we established that such a relationship does hold, as shown in Figure 5. The details of the analysis are reported in Appendix A.

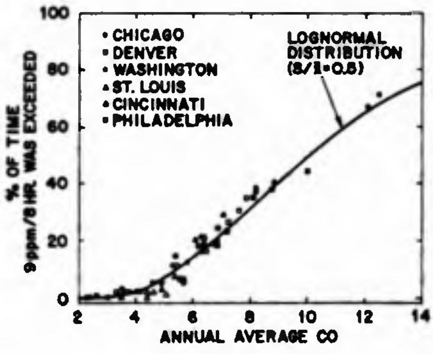


Fig. 5 - Relationship Between Exceedence of Federal 8-Hour Ambient CO Standard and Annual Average CO for All CAMP Cities

From this relationship, the annual average CO consistent with one annual occurrence of the 9 ppm - 8-hour average CO concentration was computed. This value is 2.3 ppm. An independent, strictly empirical analysis of the relationship similarly leads to the conclusion that the annual mean CO concentration consistent with achievement of the 8 hour CO standard is 2.3 ppm, with better than 98% confidence.

The annual average CO data listed in Table II show that Cincinnati and Philadelphia were close to, or already at, the required 2.3 ppm level in 1971.

TABLE II

CAMP CITY AMBIENT CARBON MONOXIDE TRENDS

	Annual Average CO Concentration, ppm					
Year	Chicago	Denver	Washington	Cincinnati	St. Louis	Philadelphia
1962			5.3			
1963			6.9	7.1		
1964	12.1		5.7	6.1	6.4	7.2
1965	17.1	7.3	3.7	4.0	6.5	8.1
1966	12.5	7.9	3.3	4.9	5.8	6.8
1967	8.8	7.6	4.9	5.6	5.6	6.4
1968	6.2	5.4	3.4	5.7	4.6	8.7
1969	8.2	4.6	3.0	-	5.1	3.5
1970	6.9	6.5	3.8	-	4.4	4.1
1971	5.4	6.7	3.5	2.3	4.4	2.6

The other cities were still above the required 2.3 ppm annual average by varying amounts, although trending downward, in general.

The one exception, Denver, has shown an increase of ambient CO since 1969, but this is apparently attributable to an excessive vehicle population mean CO emission rate resulting from the interpretation of the antitampering provision of the Clean Air Act Amendments to mean that altitude-tuning of carburetors is prohibited. As a result, vehicles at Denver's 5,000 foot elevation are running significantly rich with resultant excess CO emissions.

This explanation is verified by a recently reported EPA-sponsored survey of exhaust emissions from a total of 1,020 vehicles of the 1957-1971 model years which clearly showed that both hydrocarbons and carbon monoxide emissions in Denver were significantly higher, and oxides of nitrogen significantly lower, than in the other cities studied. As shown by the second column in Table III, the Denver 1971 vehicle population mean CO emission rate is nearly double that for Washington, D.C.

The third column in Table III was calculated from the reported 1971 annual mean CO for each city, and the requirement for a 2.3 ppm annual average to meet the air quality standard as derived earlier. When the percent reduction figures from column three are applied to the population mean CO emission rates in column two, the values in the last column are obtained, showing the CO emission rate consistent with achievement of the ambient air quality standard in each of the cities. There is good agreement among the values for Denver, Los Angeles, St. Louis, and Washington. The more stringent standard calculated to be necessary to meet the air quality standard in Chicago may well be the result of the meteorological peculiarity of that city's pronounced lake breeze effect discussed in Appendix A.

TABLE III

VEHICLE CO EMISSION STANDARDS CALCULATED BY AIR QUALITY TREND ANALYSIS, USING MEASURED 1971 VEHICLE POPULATION MEAN CO EMISSION RATES

City	1971 Population CO Emission Rate, g/Mile, CVS-75	Decrease of 1971 Annual Mean Ambient CO Required to Achieve Air Quality Standard, Percent	Required CO Emission Standard, g/Mile, CVS-75
Chicago	66.37	57	29
Denver	112.11	66	38
Los Angeles	74.44	52	36
St. Louis	74.81	48	39
Washington, D.C.	61.87	34	41

MODIFIED ROLLBACK

Because of the limitations of simple rollback, recent official EPA air quality projections have been based on a "modified" rollback model, as discussed in Appendix D. The modifications introduced by EPA are:

(1) consideration of six source categories, each with its own growth rate, and assumed degree of future emission control, and

EDITOR'S NOTE: Appendix D may be found in committee's files.

(2) Inclusion of a factor for each source category which weights the emissions according to their stack height.

With EPA's cooperation in providing us with copies of their input data and computer program, we have conducted tests of the ability of the modified rollback model to predict air quality under various control strategies. The observed air quality in three test cities was compared with the values computed from estimates of past emissions and growth rates.

These validation tests of the current EPA version of the modified rollback air quality projection model, which are discussed in detail in Appendix D, show that the error of predicted CO values is unacceptably large. The performance of the modified rollback method in projecting CO levels in Chicago is illustrated in Figure 6.

Based on our earlier analysis of the relationship between urban CO emissions and air quality, we believe this large prediction error is primarily due to that assumption of the modified rollback model which attributes equal importance to CO emissions originating anywhere within the air quality control region (AQCR). It is important to recognize that the Federal AQCR's are geographically very large, so that sources near their boundaries cannot reasonably be expected to have any significant influence on air quality in the central metropolitan area. For example, the areas of the Chicago, Philadelphia, and National Capitol AQCR's are, respectively, 6087 mi^2, 4585 mi^2, and 2326 mi^2. If these regions were circular, their outer boundaries would be 27, 44, and 38 <u>miles</u> from the center. As the regions are not circular, their farthest points are at even greater distances than those listed above. Yet, the assumption of both the simple rollback, and of the current modified rollback, is that all sources contribute to determination of air quality at a receptor point in proportion to their emission rate, regardless of their distance from the receptor.

PLANS FOR FURTHER DEVELOPMENT AND VALIDATION OF THE RELATIONSHIP BETWEEN AUTOMOTIVE EMISSIONS AND AIR QUALITY

To date, our efforts toward development of an objective methodology to relate emissions and air quality have focussed on carbon monoxide. One factor which influenced this approach is that CO is the simplest of the automotive pollutants to deal with. The data base has been essentially restricted to CAMP measurements, because these span approximately one decade, and the sampling under the CAMP program was done in urban areas chosen to be representative of of the dominant classes of U.S. cities.

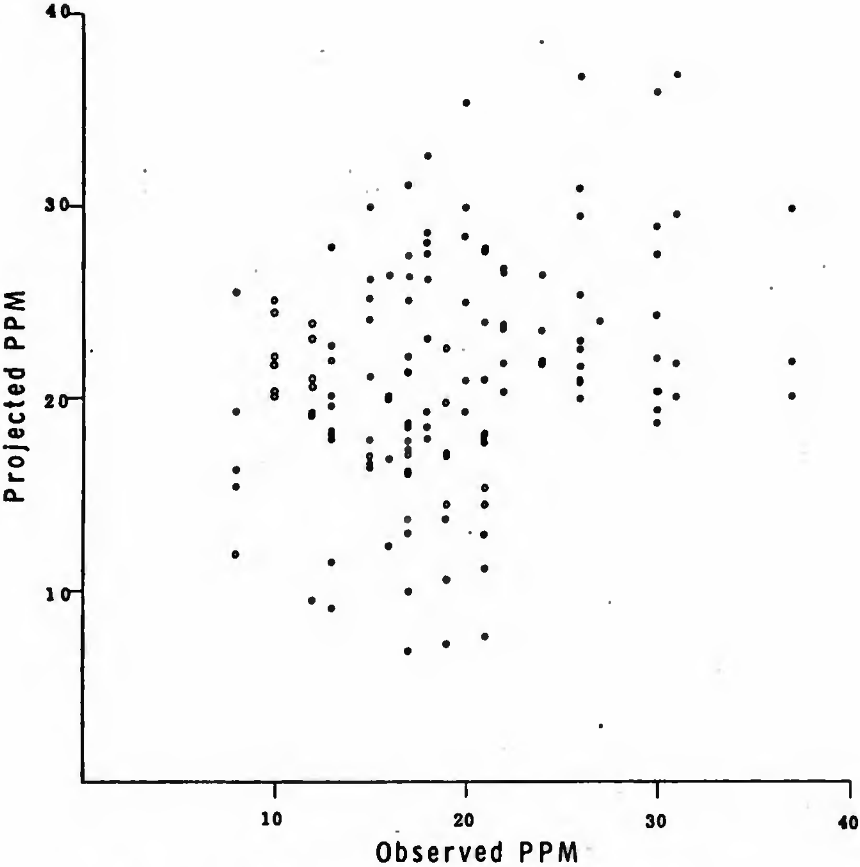


Fig. 6 Annual Second Highest 8-Hour Nonoverlapping Average CO Concentration Projected by "Modified Rollback Air Quality Impact Analysis"

The number of locations making aerometric measurements has been vastly increased in the past few years in response to the requirements of Federal legislation. However, this has not resulted in a proportionate increase in the data applicable to the problem of relating air quality and emissions, because the short time span of the records at these locations preclude confident conclusions regarding the presence or absence of trends. There is another large pool of aerometric data, going back about ten years, from the State of California air sampling program which we expect to utilize in our further work.

Our experience with the modified rollback model has underscored the vital necessity for verification of air quality projection techniques. Such verification tests not only provide the basis for objective statements of the range of applicability of projections, but may also help point directions for improvements. Accordingly, we plan to conduct further verification tests of the presently constituted modified rollback projection model as additional emissions inventory data become available to merge with historical air quality data.

We further plan to test the projection capabilities of an "adjusted" version of the modified rollback. The adjustment will be in the input data, rather than in the algorithm used for the computations. As was pointed out earlier, part - perhaps most - of the reason for the poor performance of modified rollback in forecasting CO air quality may be associated with the use of emission inventories summed over unrealistically large areas surrounding the receptor points where aerometric data are collected. A possible practicable solution to this difficulty may lie in restricting the assumed areal range of applicability of the modified rollback relation, by simply relating the air quality measurements to emissions inventories over smaller regions around the sampling point. It should be emphasized that we are not aiming at near-perfect predictive capabilities, but rather are seeking to identify a procedure which could utilize already available emissions data to upgrade the performance of modified rollback, and provide a rational basis for setting emission standards.

The other major area of our interest is an extension of the trend analysis methodology to the derivation of allowable NO_x emission rates, for achievement of the NO_2 air quality standard, and to the derivation of concurrently allowable hydrocarbon emissions, for achievement of the photochemical oxidant air quality standard. The significant contributions of non-vehicular sources to the atmospheric burdens of these pollutants complicates the picture, but as adequate emissions data become available, we will utilize them in this effort.

CONCLUSIONS

The measurements collected under the CAMP program are an important long term record of the response of air quality in selected U.S. cities to changes in emissions. Also, they provide a basis for validation of candidate models for air quality projections.

Verification tests of the simple rollback and the modified rollback models showed that, even for the simplest case of carbon monoxide, little confidence can be attached to the resultant air quality projections.

An alternative route to estimate emission standards needed to meet air quality standards, was developed based on analysis of air quality trends. It was determined that annual mean ambient CO is a usable index of achievement of the CO air quality standard. A significant practical advantage to the use of the annual mean is that it is less sensitive to error than is estimation of the second highest 8-hour average CO in a given year. It was further determined that an annual average CO concentration of 2.3 ppm is consistent with achievement of the CO air quality standard.

On the basis of the requirement for 2.3 ppm CO as an annual average, the best current estimate of the required vehicle carbon monoxide emission rate for the worst urban area is approximately 29 g/mile.

DESIGN AND PERFORMANCE OF DU PONT LEAD TRAP SYSTEMS

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August 30, 1973

PERFORMANCE OF DU PONT MUFFLER LEAD TRAPS

Summary

The Du Pont muffler lead traps have been developed to remove the major portion of the particulate lead material from the exhaust of vehicles operated on conventional leaded gasoline. These units are essentially the size and shape of a conventional muffler and are located in the same position under the car. The trap contains a bed of alumina pellets to agglomerate the fine lead particles in the exhaust into larger particles. The lead particles are separated from the exhaust gas stream by an inertial cyclone separator and stored in an appropriately sized collection chamber. The choice of materials of construction and the size of the collection chamber can be varied to give a ueeful life of the trap of from 40,000 to 100,000 miles.

Muffler lead traps have been operated on a wide variety of cars - both production vehicles as well as those equipped with advanced gaseous emission control systeme. Total lead emissions were reduced by 80 to 90 percent during long-term tests of up to 100,000 miles and the fine lead particles which could be airborne were reduced by 70 to 80 percent compared with cars equipped with conventional mufflers. The effectiveness of the traps did not change with mileage accumulation and no maintenance was performed on the trape. The effectiveness of these traps has been confirmed by tests run by three independent laboratories other than Du Pont including tests by the Dow Chemical Company run under contract to the EPA. A field test of the muffler lead traps is being run in conjunction with the San Francisco Bay Area Air Pollution Control District. Results for the first year show that the traps reduced lead emissions from these cars by approximately 90 percent.

Estimates of the cost of "retrofit-type" muffler lead traps which were built by Arvin Industries to the exact dimensions of a conventional muffler show the incremental manufacturing cost to be approximately $5 more than the conventional muffler. These "retrofit-type" traps reduced lead emissions by approximately 70 percent compared with cars equipped with conventional mufflers.

Recent results covering the performance of these muffler lead traps are given in the following five sections which cover: (1) lead emission measurements, (2) Du Pont lead trap, (3) Pinto trap, (4) the field test in San Francisco, and (5) cost estimates. Additional tests, design details, and a description of test procedures are given in the appended references.

I. MEASUREMENT OF LEAD EMISSIONS

One of many problems related to lead trap development is actual measurement of lead emissions from cars. EPA has stated that emission rates as measured by different investigators vary widely (Ref. 1). We have pointed out to the EPA the inconsistences in their evaluation of vehicle particulate emission data and have described the reasons for variability of lead emission rates from standard production vehicles (Ref. 2). In order to obtain an average baseline value for lead emissions from uncontrolled vehicles it is necessary to make measurements over the entire life of several cars using a representative driving cycle. A second approach is to measure the lead emission rate from a large number of similar size cars using the same fuel lead content and driving cycle. A large number of vehicles are required to obtain a good average since cars will have very erratic total lead emissions even with identical test cycle and similar driving history.

In contrast to standard vehicles the trap-equipped cars show a constant lead emission rate which should enable more accurate measurement of lead emissions. To prove the performance and substantiate our claims of lead reduction by lead traps we have obtained measurements of lead emission rates of several trap-equipped cars by three other investigators. As shown by the data in Table 1, Esso and Du Pont obtained almost the same lead emission rate value from a car equipped with a Type III muffler lead trap. For each test value reported by Du Pont and Esso, the car was driven on a dynamometer for one 1972 Federal Test Procedure cycle (7-1/2 miles) from an initial cold start after an overnight soak. Esso measured lead emission rate with their sampling system (Ref. 3) while Du Pont employed the total exhaust filter procedure (Ref. 4).

A second car, equipped with an advanced gaseous emission control system plus muffler lead traps, was driven to Ethyl Corporation, Detroit and Dow Chemical Company, Midland, Michigan for particulate emission measurements. The lead emission rate as measured by these two laboratories using slightly different driving conditions show excellent agreement. The same car was retested at the Petroleum Laboratory after returning from the Michigan trip.

The agreement between various investigators for particulate lead emission measurement on trap-equipped cars is excellent.

TABLE 1

LEAD EMISSIONS MEASURED BY DIFFERENT LABORATORIES

	Test Mode	Lead Emissions, g/Mile	
		Du Pont	Esso
1970, 350 CID Chevrolet With Type III Lead Trap	FTP 1972	0.018	0.019

		Dow	Du Pont	Ethyl
1970, 350 CID Chevrolet With Thermal Reactor, EGR	FTP 1975	0.019* 0.023	0.017	-
Dual Type III Lead Traps	FTP 7-Mode	-	0.018	0.021

* Corrected for filter lead blank

II. MUFFLER LEAD TRAP - TYPE III

The Du Pont muffler lead trap, designated Type III, is shown in Figure 1. The internal components have been arranged to provide a volume of the cyclone collection chamber designed to hold all the lead salts burned during 50,000 miles of operation. The trap is made of 304 stainless steel and weighs 17 pounds without pellets, about the same as a standard muffler. It is filled with 10 pounds of one-quarter inch alumina pellets.

Identical Type III muffler lead traps were installed on each of four 1970, 350 CID Chevrolets as shown in Figure 1. Each unit was installed in place of the exhaust muffler. These cars were operated on programmed chassis dynamometers according to the Federal mileage accumulation schedule. During this mileage accumulation test, the lead emissions were measured with total exhaust filters throughout the test. The average total lead emission rate for these four cars and the average percent lead burned emitted for each car during the life of the test are summarized in Table 2.

TABLE 2

DU PONT MUFFLER LEAD TRAPS
TYPE III ON 1970 CHEVROLETS

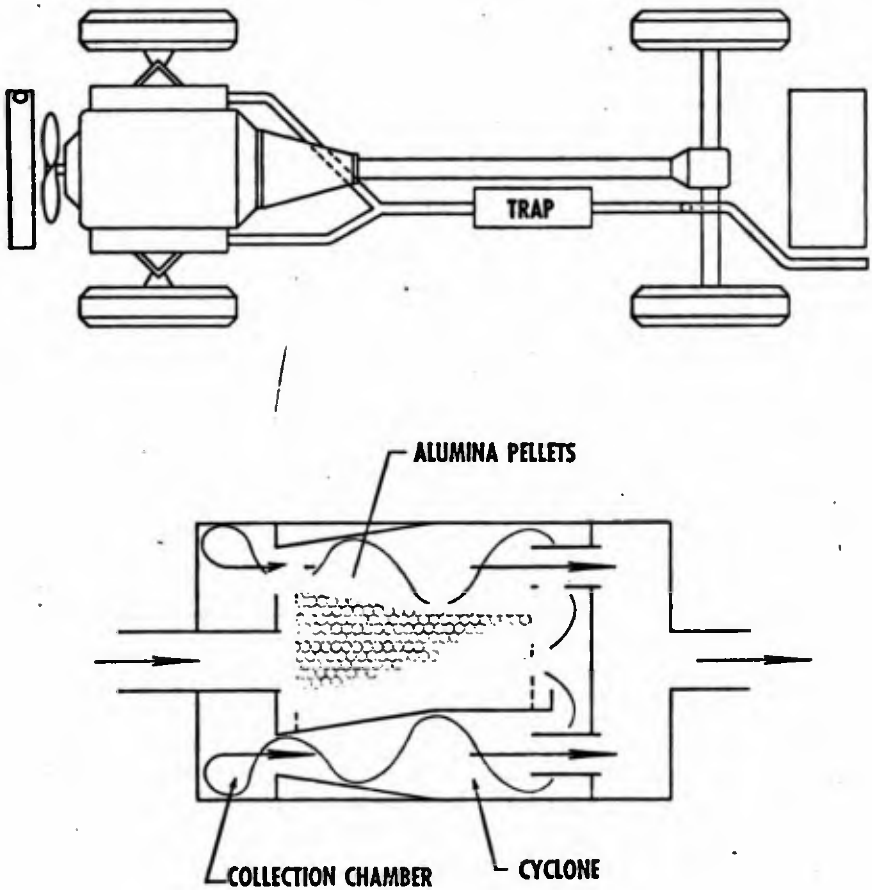
Vehicle	Miles on Trap	% Reduction of Lead Emitted: Total	% Reduction of Lead Emitted: Airborne
C-82	52,669	88	68
C-83	21,790	85	72
C-85	50,102	89	64
C-130	12,440	92	-
	Average	88	68

The weighted average total lead emission rate from these four Chevrolets equipped with the Type III muffler lead trap was 0.015 gram per mile for over 50,000 miles. This is equivalent to an 88 percent reduction in total lead emissions when compared with a standard car operated under the same conditions and same fuel. The average percent lead burned emitted was slightly less than 12 percent.

Lead particulate emissions from cars with standard exhausts vary much more erratically than cars equipped with lead traps as shown in Figure 2. This also shows that the average lead emission rate from a car equipped with a conventional exhaust system was still increasing after 30,000 miles. The lead emission rate from a car equipped with a muffler lead trap showed very little variation and even after 40,000 miles was constant and essentially the same as the rate at very low mileage. The increase in lead emissions with mileage and erratic lead emission behavior of cars with standard exhaust systems is due to the continuous build-up

Figure 1

Du Pont Muffler Lead Trap - Type III



and reentrainment of lead deposits from the inside surfaces of the exhaust pipe as well as the muffler. This variability of lead emissions does not occur with trap-equipped cars because the cyclones at the end of the trap retain these particles. This would indicate that lead emissions from such trap-equipped cars can be more accurately measured than total lead emissions from uncontrolled cars. Thus, it is much more difficult to establish a baseline particulate lead emission rate of standard production cars than it is to measure the performance of lead traps.

In addition to reducing the total lead emissions, the muffler lead traps also significantly reduce the amount of the small, air-suspendible lead particles emitted to the atmosphere. The results of particle size and size distribution of lead particles emitted from the trap-equipped vehicles measured after 15,000 and 50,000 miles are given in Table 3. As expected, the lead traps with their inertial separators were effective in removing almost all of the large particles which come from material that flakes off the walls of the exhaust system. This is the material which if emitted settles to the ground rapidly and is probably the major source of dustfall lead, particularly near heavily travelled roads and highways. Of special interest is the 68 percent reduction in the submicron size lead particles. The reduction in emission in these small particles is most important since these are the lead particles which tend to remain airborne and which correspond to the size of lead particles found in the atmosphere of urban areas. It is also important to note that the efficiency of the traps for removal of these small particles did not deteriorate with mileage, but remained essentially the same at 50,000 miles as at 15,000 miles. This is further proof that pellets did not deteriorate with mileage. It also indicates the activity of the fresh alumina surface is not the most important property of the pellets, since the pellets tend to become coated with lead salts with extended mileage. The high surface area and temperature appear to be much more important factors in trapping the lead.

The durability of the muffler lead traps is excellent. Several of the traps were removed from the cars, opened, and examined after 50,000 miles of operation. The alumina pellets were undamaged and showed only slight attrition. The pellet bed was not plugged and the bed back pressure did not increase over the original value during 50,000 miles of operation. The fuel economy and acceleration of the trap-equipped cars was the same as that of cars with conventional exhaust systems.

A lead material balance on C-82 showed the trap collected 61 percent of the lead burned. Lead analysis showed the trap gained 15 pounds weight during 50,000 miles of which nine pounds was lead. Approximately 28 percent of the lead was retained on the pellets. A complete summary of the lead distribution is given in Tables4 and 5.

Figure 2

Lead Emission Rate From Car With Standard Exhaust and a Car With a Muffler Lead Trap

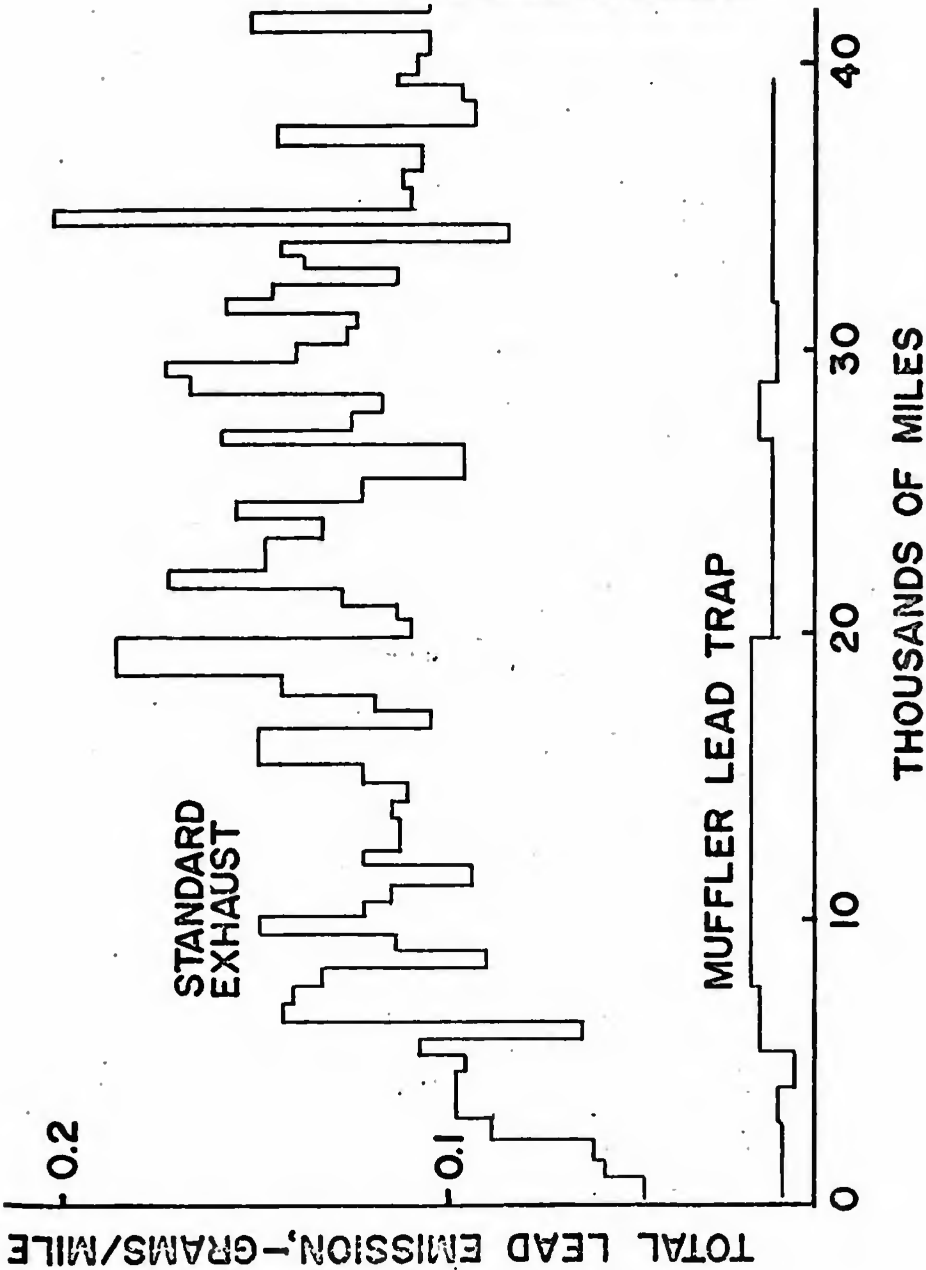


TABLE 3

TYPE III MUFFLER LEAD TRAP PERFORMANCE ON 1970 CHEVROLETS

Vehicle	Mileage	Lead Emission Rate, Grams/Mile As Function of Equivalent Particle Diameter				
		> 9 μm	1 to 9 μm	0.3 to 1.0 μm	< 0.3 μm	Total
Standard Car*	Mean	0.038	0.023	0.019	0.028	0.108
C-82	14,500	0.00076	0.0024	0.0022	0.015	0.020
C-83	3,300	0.00056	0.0031	0.0040	0.011	0.019
C-85	9,000	0.00074	0.0021	0.0020	0.011	0.016
Average		0.00069	0.0025	0.0027	0.012	0.018
% In Each Fraction		4	14	15	67	100
% Reduction Due to Trap		98	89	84	59	84
C-82	53,600	0.0007	0.0053	0.0055	0.011	0.023
C-85	51,200	0.00051	0.0029	0.0041	0.095	0.017
Average		0.0006	0.0041	0.0048	0.0103	0.020
% In Each Fraction		3	20	24	53	100
% Reduction Due to Trap		98	82	75	63	81

TABLE 4

LEAD BALANCE OF MUFFLER LEAD TRAP
TYPE III FROM C-82

Vehicle: 1970, 350 CID Chevrolet
Fuel: Sun 240, 2.2 g Lead Per Gallon
Miles: 52,669 Miles on AMA Cycle

	Lead, Grams	% Lead Burned
Lead Trap		
Cyclones	2,500	37.8
Pellets	1,240	18.7
Scrapings	300	4.5
	4,040	61.0
Total Filter	794	11.9
Estimated		
Oil & Oil Filter		11
Engine		3
Manifold & Exhaust Pipes		8
Total Accounted For		94.9
Total Pb Burned		

$$\frac{52{,}669 \text{ Miles X } 2.2 \text{ g Pb/Gallon}}{17.4 \text{ mpg}} = 6{,}630 \text{ grams}$$

TABLE 5

COMPOSITION OF LEAD DEPOSITS IN MUFFLER LEAD TRAP TYPE III FROM C-82

Vehicle: 1970, 350 CID Chevrolet
Fuel: Sun 240, 2.2 g Lead Per Gallon
Miles: 52,669 Miles on AMA Cycle

Compound	Weight %
PbBrCl	54
$PbSO_4$	19
$PbBr_2$	11
$Pb_3(PO_4)_2$	3
PbO	13

III. 100, 000-MILE TEST OF LEAD TRAPS ON TECS VEHICLE

The Du Pont muffler lead trap has also been installed on vehicles equipped with lead tolerant advanced emission control systems to produce a Total Emission Control System or TECS vehicle (Ref. 5, 6). The components of the TECS installed on a 1.6 liter 1971 Pinto are shown schematically in Figure 3. The trap is installed on the Pinto in the same location as the conventional muffler on a current production vehicle. The muffler lead trap unit is the same design as that shown in Figure 1. The exhaust manifold thermal reactor is used in conjunction with an air pump to provide a high temperature zone where the hydrocarbons and carbon monoxide in the exhaust are oxidized. An exhaust gas recirculation system is combined with various carburetor modifications to control the emissions of oxides of nitrogen. A more complete description of the vehicle and its performance in controlling gaseous emissions can be found in References 5 and 6.

The lead emission rate from this TECS vehicle has been measured and the data are summarized in Table 6. The Pintos were operated under a mixed duty cycle consisting of city-suburban road driving on the highway and turnpike operation on the programmed chassis dynamometer. Total lead emissions from the Pinto were measured during both road and PCD operation. The average total lead emissions from the TECS Pinto were reduced by 81 percent by use of a muffler lead trap after operating for 101, 000 miles on the road and the PCD. There was no deterioration in the Pinto lead trap performance with mileage. The actual lead emissions from the TECS Pinto were equivalent to only 8 percent of the total lead burned. Thus 92 percent of the lead burned was retained in the vehicle.

In addition to measuring the total lead emission rates, the particle size distribution of the emitted lead from the Pinto was determined. The values for the standard and trap-equipped Pintos are shown in Table 6. Each datum is the mean of three replicate runs. The cars were driven on a Clayton dynamometer for three AMA cycles (120 miles) per run from an initial cold start after an overnight soak. The gasoline contained 2.2 grams lead per gallon as Motor Mix.

Under the AMA cycle the trap reduced total lead emissions by some 84 percent. Examination of the size distribution of the emitted lead reveals that, as expected, the trap was effective in reducing particles of all sizes. The lead particles with size greater than nine microns which would fall to the ground rapidly were reduced by 98 percent. There was an 87 percent reduction of the one to nine micron fraction, an 88 percent reduction of the 0.3 to 1 micron, and a 77 percent reduction in the mass of particles less than 0.3 micron diameter. These results further establish the effectiveness of the muffler lead traps to reduce small and large particles over extended mileage.

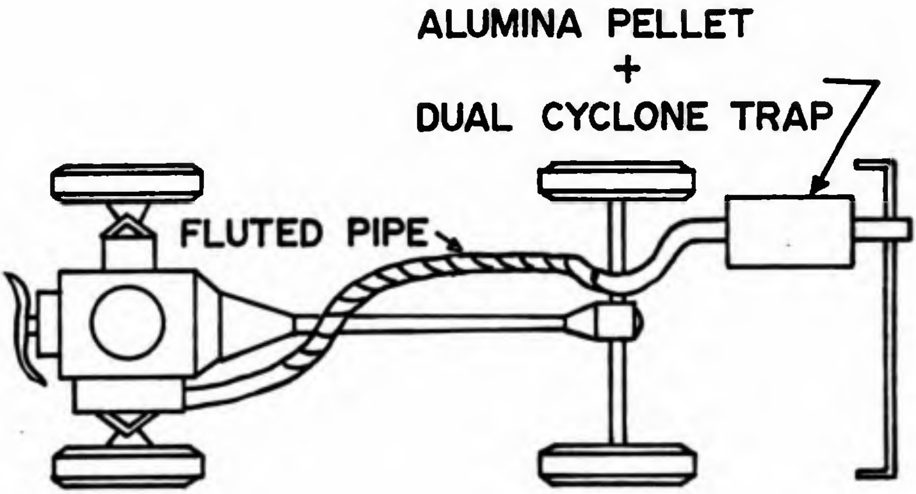


Fig. 3 — Diagram of Muffler Lead Trap on 1971 Pinto.

TABLE 6

DU PONT TOTAL EMISSION CONTROL SYSTEM (TECS)

(Thermal Reactor, Exhaust Gas Recirculation, Lead Trap)

Vehicle	System Miles	Total Lead Emissions g/Mile	Total Lead Emissions % Reduction
1.6 Liter 1971	25,000	0.033	-
Production Pinto	50,000	0.035	-
	75,000	0.032	-
	101,000	0.033	-
1.6 Liter 1971	25,000	0.0070	80
Pinto With TECS	50,000	0.0063	82
	75,000	0.0056	83
	101,000	0.0063	81

TABLE 7

SIZE DISTRIBUTION OF LEAD EMISSIONS FROM TECS PINTO

	Lead Emission Rates, Grams Per Mile, as Function of Particle Equivalent Diameter in Micrometers				
	> 9.0	1.0 to 9.0	0.3 to 1.0	< 0.3	Total
Unmodified 1971 Production					
20,000 Miles	0.019	0.018	0.024	0.036	0.097
51,000 Miles	0.013	0.016	0.037	0.051	0.117
Average	0.016	0.017	0.030	0.044	0.107
TECS With Trap					
26,000 Miles	0.0005	0.0016	0.0024	0.0075	0.0120
51,000 Miles	0.0003	0.0029	0.0049	0.0129	0.0210
Average	0.0004	0.0022	0.0036	0.0102	0.0165
Reduction, Percent	97.5	87	88	77	84

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IV. SAN FRANCISCO FIELD TEST

As a further demonstration of the feasibility of lead traps, a field test is under way of Du Pont muffler lead traps installed on four cars in San Francisco, California. The test is being conducted in cooperation with the Bay Area Air Pollution Control District, who own and operate the four cars. The exhaust muffler on each of two 1971 and 1972, 6-cylinder, 258 CID Hornets was removed and replaced with a retrofit muffler lead trap. The trap design is similar to the Type III described in Reference 6. The traps, designed to last 50,000 miles are sized and shaped like and installed in the same position as the conventional Hornet muffler which it replaced.

After each three months of road service, the total lead emissions are measured with a total filter (Ref. 4) with the vehicle operated according to the 1968 Federal Test Procedure on a chassis dynamometer. Each car is driven on the dynamometer for a distance of 22.5 miles (25, 137 second, 7-mode cycles) using the vehicle's tank fuel which usually contains about 3.0 grams of lead per gallon.

After one year of service during which the cars have accumulated from 11,000 to 28,000 road miles, as shown in Table 8, the traps reduced the average lead emissions from these cars to 0.0072 gram per mile, equivalent to 4.3 percent of the fuel lead burned.

Du Pont has been operating three similar vehicles on a programmed chassis dynamometer to serve as controls for the San Francisco field tests. Two of the cars are equipped with standard exhaust systems while the third has a trap which is identical to the ones in San Francisco. The results of the tests of these cars operated under the same driving schedule as the field test cars is shown in Table 9. The two production cars emitted 0.086 g Pb per mile or 45.7 percent of the lead burned. The trap-equipped car emitted 0.019 g Pb per mile or 9.7 percent of the lead burned.

When the cars in the field in San Francisco are compared with the standard cars it is clear that the traps reduced the lead emitted by 88 to 92 percent.

TABLE 8

SAN FRANCISCO FIELD TEST OF DU PONT MUFFLER LEAD TRAPS ON 258 CID, 1971-72 HORNETS

Vehicle	Trap Mileage		Total Lead Emissions g Pb/Mile	Total Lead Emissions % Pb Burned
53	3,224		0.0024	1.7
	7,221		0.0081	5.8
	14,077		0.0057	3.7
	19,519		0.0064	4.1
		Average	0.0057	3.8
33	1,656		0.0013	0.7
	6,781		0.0091	5.2
	10,684		0.0044	2.3
	16,964		0.0023	1.3
		Average	0.0043	2.4
22	4,179		0.0042	2.6
	14,353		0.0055	3.2
	22,596		0.0064	3.7
	28,203		0.0091	5.4
		Average	0.0063	3.7
64	1,566		0.0067	3.6
	4,960		0.0075	4.4
	8,131		0.0228	13.7
	11,414		0.0128	8.2
		Average	0.0124	7.3
1-Year 4-Car Average	19,025		0.0072	4.3

TABLE 9

DU PONT LEAD TRAP ON 258 CID, 1971 HORNET

Vehicle	Test Miles*	Average Total Lead Emitted g/Mile	% Lead Burned
HO-2 Standard Exhaust	12,977	0.094	47.4
HO-3 Standard Exhaust	6,480	0.079	44.3
HO-4 Muffler Lead Trap	6,461	0.019	9.7

* PCD operation under continuous 1968 FTP (7-mode cycle) Conditions on fuel containing 3.0 g Pb/gallon

V. COST ESTIMATE OF DU PONT MUFFLER LEAD TRAPS

Du Pont estimated the price of a muffler lead trap which was made to the exact outer dimensions of a conventional muffler for a 1970 Chevrolet in late 1972. As detailed in Reference 2, the manufacturing cost of such a retrofit muffler lead trap was estimated to be \$9.38 compared with \$4.50 for a conventional muffler and the maximum consumer cost was estimated to be \$36.00 compared with \$17.30 for a conventional muffler. Since this estimate was made, cost estimates have been received from Arvin Industries and Questor Automotive Products Company. Their estimates are compared with the Du Pont estimate in Table 10.

The cost estimates by the two muffler manufacturers are in good agreement and agree very well with the estimate by Du Pont. We have extrapolated the cost estimates by Arvin back to a manufacturing cost of \$4.50 for the muffler. With the same ratio of trap to muffler cost of 2.03 at the manufacturing level as at the various wholesale and retail levels the extrapolated manufacturing cost of the trap would be \$9.15 or quite close to the Du Pont estimate of \$9.38.

As discussed in detail in Reference 2 the proper markup to be applied to the manufacturing cost of a trap to determine consumer cost is open to question. Apparently, Arvin and Questor applied the same percent markup as with a conventional muffler. This method would mean much greater profits for everyone in the distribution chain and whether this would actually happen in the market place cannot be predicted. The minimum increase in cost at the motorist level would be the incremental manufacturing cost of \$4.65 and the maximum would be \$21.03 which would occur if the same percent markup were applied. The truth probably lies somewhere between these two extremes.

TABLE 10

COST ESTIMATES FOR DU PONT MUFFLER LEAD TRAP
OF EXACT SIZE AND SHAPE AS CONVENTIONAL MUFFLER

	Du Pont		Arvin		Questor
	Muffler	Trap	Muffler	Trap	Trap
Manufacturing Cost	$ 4.50	$9.38	($4.50)*	($9.15)*	
Warehouse Selling Price			9.26	18.79	$18.00
Jobber Selling Price To Motorist	17.30	36.00	17.30	35.16	
Garage Selling Price To Motorist			20.37	41.40	43 to 44

* Extrapolation by Du Pont

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Du Pont Petroleum Chemicals

Tech Memo

E. I. DU PONT DE NEMOURS & CO. (INC.) • WILMINGTON, DELAWARE 19898

Technical Memorandum Auto-8024

FUEL CONSUMPTION AND PERFORMANCE OF 1973 VERSUS 1967 STANDARD SIZE AUTOMOBILES

Trends in fuel economy/consumption and performance of car models produced since the incorporation of emission control devices beginning with 1968 model cars have been the subject of a number of recent publications. The results reported by Du Pont in a recent paper (Reference 1) presented before the American Petroleum Institute Division of Refining Meeting are updated in this memorandum and compared with results reported in an EPA publication (Reference 2) and two Society of Automotive Engineers papers (References 3 and 4) presented by representatives of Ford and Chrysler at the 1973 SAE National Automobile Engineering Meeting. From a comparison of the results reported in these papers, it is estimated that for representative full size cars produced from 1968 to 1973 there has been:

(1) A net deterioration in performance (increased time to accelerate from 0 to 60 miles per hour) of about 12 percent because of:

	increased car weight	12%
	reduced compression ratio	7
	emission control measures	3
offset by:		
	increased engine size	(10)
	net	12

(2) An increase in fuel consumption of about 25 percent because of:

	increased car weight	7%
	increased engine size	3
	reduced compression ratio	8
	emission control measures	9
offset by:		
	improved tires and suspension	(2)
	net	25

Cars of the size discussed in this memorandum represent approximately half of U.S. domestic sales, having declined from about 54 percent of the market in 1967 to 48 percent at present. Concurrently, there has been a marked increase in the proportion of economy cars sold and an accompanying decrease in purchases of high-performance automobiles. As a result, the difference in fuel consumption per mile between the average 1973 car and the average 1967 car may not be as great as would be indicated by the figures summarized above. It is apparent, however, that the factors operating to affect the fuel consumption of larger cars will also affect fuel usage of smaller cars in a similar manner. Consequently, decreasing car weight and increasing compression ratio represent effective and promising routes for decreasing fuel consumption.

PETROLEUM LABORATORY STUDIES

Description of Cars Used in Program

Trends in fuel consumption and performance of car models produced beginning with the 1970 model year have been studied at the Petroleum Laboratory using in each successive year current model vehicles duplicating as closely as possible the original 1970 cars. The cars selected in 1970 were all equipped with V-8 engines and automatic transmissions. Over the years all cars have been matched as to air conditioning, number of carburetor barrels and accessories such as power brakes and power steering. All cars were operated at least 5000 miles before consumption and performance testing. Information on the individual cars is summarized in Table I.

Table I

Cars Used in Fuel Consumption Program

V-8 Engines
Automatic Transmissions
1970 to 1973 Models

Car Make	Air Conditioning	Displacement CID	Carburetor Barrels
A	Yes	350	2
C	Yes	455	4
D	Yes	400	2
E	Yes	351	2
F	No	302	2
G	No	318	2

From 1970 to 1971 the compression ratio of most engines was decreased significantly with some additional reduction in the average for all cars for 1972 and 1973 models. As shown in Table II on the following page, and in more detail in Table I of the Appendix, the average compression ratio declined 0.9 unit from 1970 to 1971 and 0.1 additional unit in both 1972 and 1973. Averages for the six cars were within 0.1 ratio of weighted U.S. car averages based on studies of Coordinating Research Council Octane Number Requirement Surveys for 1970, 1971, and 1972 (References 5, 6 and 7).

The weight of the cars was determined using calibrated scales and is shown in Table II of the Appendix. As shown in Table II below, the weight of the vehicles increased each model year with the average increasing 291 pounds from 1970 to 1973. About half of this increase (147 pounds) occurred between 1972 and 1973 models and is associated primarily with safety standards involving bumpers. A change in construction of Model F from unit body to frame and body coincided with an increase of 510 pounds for that car from 1971 to 1972.

Table II

Changes in Compression Ratio and Weight of Vehicles Used in Du Pont Program

	1970	1971	1972	1973
Average Compression Ratio*	9.5	8.6	8.5	8.4
Average Weight	4362	4403	4505	4653

* Manufacturers' published number.

Changes, too many to enumerate, were made to the vehicles by their manufacturers throughout the period to meet the successively more stringent U.S. Vehicle Emission Standards as given in Table III. The engine changes affected principally carburetion, ignition timing, valve timing, and exhaust gas recirculation. Transmission characteristics also were altered to some extent.

Table III

U.S. Vehicle Emission Standards - 1968 to 1974

Year	Exhaust Emissions, Grams/Mile HC	CO	NO_x	Evaporative Emissions, Grams/Test
1968 Federal Test Procedure (7-Mode)				
Pre-1968	(11)	(80)	(4)	(60)
1968-1969	3.2	33.0	-	-
1970	2.2	23.0	-	-
1971	2.2	23.0	-	6.0
1972 Mass Emission Test Procedure (CVS-72)				
Pre-1968	(16.8)	(125)	(4.5)	(60)
1972	3.4	39	-	2.0
1973-74	3.4	39	3.0	2.0

( ) Numbers in parentheses are estimates.

Performance (Time to Accelerate)

Performance was measured by determining the time to accelerate from 0 to 60 miles per hour and 25 to 60 miles per hour. Speed and time were plotted automatically with signals from a speed sensor on a fifth wheel. Acceleration times were determined by examination of the plotted data. Six repeat accelerations were run, three in each direction, on a straight and level section of a public highway. Results are expressed on the basis of the average of the times in seconds for the six accelerations.

As shown in Table IV, an increase of 13 percent in acceleration time occurred between the 1970 and 1971 models. This increase probably is associated with the reductions in compression ratio and changes made to meet the emission standards. Additional increases were seen also between 1971 and 1972 models and 1972 and 1973 models. When the cumulative increase from 1970 to 1973 was calculated based on the individual changes in each year, the acceleration times apparently increased about 22 percent. In view of this rather large change in vehicle performance, the 1970 vehicles which had been retained at Du Pont were run in direct match against the 1973 vehicles in early 1973. These evaluations showed that the differences between the 1970 and 1973 fleets were only 14 and 10 percent rather than 21 and 22 percent. Although the vehicles were checked thoroughly and adjusted to meet manufacturer's specifications, no explanation was found for the fact that the 1970 vehicles were not capable of repeating the acceleration times that they had displayed when they were new. Perhaps the accumulation of approximately 30,000 miles had caused some deterioration in engine performance which was not detectable by conventional diagnostic techniques. However, it is clear that there has been a significant decrease in vehicle performance between the years 1970 and 1973 and the acceleration times of passenger cars have increased by at least 10 percent.

Table IV

Acceleration Time Changes
1970 to 1973

Model Tested	Acceleration Time, Seconds 0-60	25-60	Percent Increase Over 1970 0-60	25-60
1970	10.7	7.8	-	-
1971	12.0	8.5	12	9
1972	12.2	8.8	14	13
1973	13.0	9.5	21	22
Direct Comparison Made in 1973 Test - 1970 vs 1973				
1970	11.4	8.6	-	-
1973	13.0	9.5	14	10

Fuel Economy (Miles Per Gallon) and Fuel Consumption (Grams Per Mile)

Fuel consumption was measured by driving over a 26-mile urban-suburban course illustrated in Figure 1 of the Appendix which included approximately nine miles of city traffic and 17 miles of suburban and interstate highways. A summary of the test course is outlined in Table V. More time was spent in city traffic than on the highway. The test vehicles were fueled from auxiliary tanks located in the trunk and the fuel consumed was determined by weight difference.

Table V

Urban-Suburban Fuel Consumption Road Course

	City	Suburbs	Overall
Miles	9	17	26
Time, Minutes	44	20	64
Speed, mph	12.3	51.0	24.4

The vehicles were tested in matched pairs so that they travelled the course in almost identical time to insure that variations in traffic and thus variations in average speed on the course did not unduly influence the results. The drivers and the position of the cars were rotated and replicate tests of at least four determinations on each matched pair were made. Because of changes in traffic lights in the city portion of the test course the average speed decreased from a value of 28.6 mph in 1970 to an average value of 24.4 mph in 1973. Thus, it was not correct to compare data obtained several years ago with current data because the fuel consumption was affected by speed. A minor change has been made recently in the city portion of the driving to avoid some of the more congested streets and the average speed over the course is now about 30 mph or much closer to the value obtained when the course was originally set up in 1970.

To compensate for the variations in speed in recent tests, the relationship between speed and fuel usage was determined by linear regression analysis and all fuel consumption data were normalized to an average course speed of 24.4 mph. The time required to complete the test is a reflection of the amount of time spent in traffic (since the suburban part of the test could be driven consistently at posted speed limits). The relationship between speed and fuel economy for one of the cars in the test is shown in Figure 1, while the equations for all cars are given in Table VI. The relationship of fuel economy and average speed shown in Table VI is, of course, only appropriate to the particular course; more conventional relationships are shown in Table VII for fuel economy measured on the road at various constant speeds.

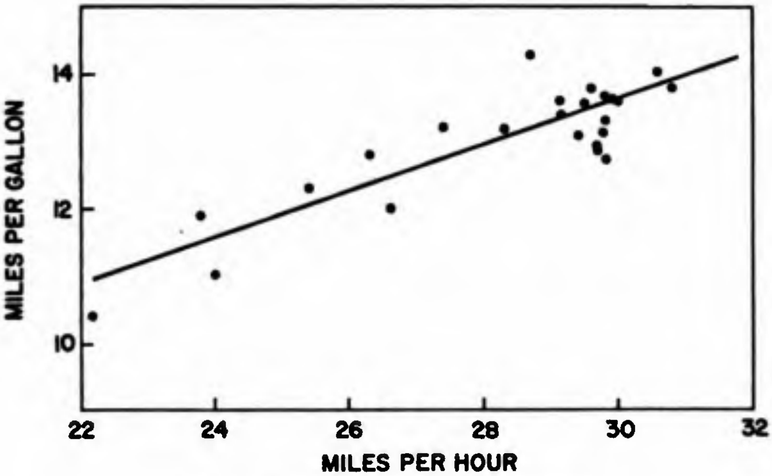

Fig. 1 — Fuel Economy Versus Speed; Urban-Suburban Course; Car Make C.

Table VI

Miles Per Gallon Versus Miles Per Hour

Urban-Suburban Test Course - 24.4 mph Average

Car Make-Year	Slope x 24.4 mph	+	Intercept	=	MPG
A - 1970	0.239 x 24.4		6.46		12.3
1973	0.375 x 24.4		1.78		10.9
C - 1970	0.342 x 24.4		3.34		11.7
1973	0.208 x 24.4		5.73		10.8
D - 1970	0.308 x 24.4		4.50		12.0
1973	0.372 x 24.4		1.58		10.6
E - 1970	0.150 x 24.4		10.01		13.7
1973	0.144 x 24.4		7.86		11.4
F - 1970	0.342 x 24.4		5.79		14.2
1973	0.406 x 24.4		1.69		11.6
G - 1970	0.163 x 24.4		11.28		15.2
1973	0.202 x 24.4		8.94		13.9
Average - 1970					13.2
1973					11.5

Table VII

Fuel Economy Versus Level Road Speed
1970 Versus 1973 Cars

	Level Road Speed			
	40	50	60	70
1970 Cars*	20.8	19.1	17.4	14.9
1973 Cars*	18.1	16.4	15.6	13.5
Average Decrease %	12.8	13.9	10.3	9.1

* Cars listed in Table I less Make F.

Fuel consumption of the 1973 cars is greater than for the corresponding 1970 cars as shown in Table VIII. Fuel consumption increased each year, the increases ranging from 6 to more than 9 percent. The cumulative fuel consumption increase between 1970 and 1973 calculated based on the individual changes for each year was 24 percent. Because of the implications of changes of this magnitude it was decided to make a direct check between the 1970 and 1973 model cars.

Table VIII

Fuel Consumption by Model Year

			Fuel Usage			
Year Of Test	Speed mph	Models Tested	Economy Miles/Gal	Percent Loss	Consumption Grams/Mile	Percent Increase
1970	28.6	1970	14.1		199	
		1971	13.1	7	214	8
1971	24.9	1971	13.1		214	
		1972	12.4	5	226	6
1972	24.4	1972	12.7		221	
		1973	11.6	9	242	9.5
Cumulative 1970 to 1973				19		24
1973	24.4	1970	13.2		213	
		1973	11.5	13	244	16
1973*		1970	13.3		211	
		1973	11.7	12	239	13

* Calculated from exhaust analysis during 1975 Mass Emission Test Procedure (CVS-75).

When the 1970 cars were directly matched against the 1973 model cars the fuel consumption of the 1973 cars was found to be 16 percent greater than for the 1970 cars. All of the fuel consumptions were regressed against average test speed and all data normalized to an average vehicle speed of 24.4 mph, as given in the lower part of Table VIII. To further check these measurements, triplicate emission tests were made on each of the vehicles and the fuel consumption calculated based on exhaust emission analysis while conducting the 1975 CVS Federal emission test procedure. These are also shown in Table VIII. The fuel consumption increase was 13 percent for the 1973 models when compared with the 1970 model vehicles.

The discrepancy between the direct determinations of the fuel consumption of the 1970 and 1973 vehicles and the calculated cumulative effect based on individual model year results has not been explained at this time. However, it is believed that the most recent comparisons, because of the greater number of tests and the fact that direct match tests were made, are more accurate.

About one-third of the increase in fuel consumption of the six cars between 1970 and 1973 was determined to be due to increased weight. The other two-thirds of the increase was due to reductions in compression ratio and changes made to control emissions. The effect of increased weight on fuel consumption was determined directly. The weight of the 1970 vehicles was increased 500 pounds by placing weights, equally distributed, in the front and rear passenger compartments. Replicate, direct match fuel consumption measurements were made with the 1970 vehicles with and without the additional weights. The average fuel consumption data for the individual 1970 and 1973 vehicles were normalized to an average speed of 24.4 mph and are shown in Table IX and Figure 2. The fuel consumption for the 1970 vehicles plus a sufficient amount of weight so that they equalled the weight of the 1973 vehicles is given also. The increase in fuel consumption of the individual 1973 cars ranged from 1 percent to 19 percent greater than for the 1970 cars at equal vehicle weights. The six-car fleet average increase in fuel consumption at equal weight was 11.4 percent for the 1973 cars compared with the 1970 cars. (The information in Table IX and Figure 2 differ slightly from comparable data given in Reference 1 due to incorporation of additional test results.)

The 11 percent increase in fuel consumption and the 10 percent increase in acceleration time can be attributed to the reduction in compression ratio and other engine changes to meet emission standards. If vehicle performance as judged by accelerating ability had been held constant, the increase in fuel consumption would have been even greater.

Table IX

Effect of Emission Controls and Compression Ratio Reduction on Fuel Consumption, 1970 to 1973

Average Speed 24.4 mph

	Economy Miles/Gal	Percent Loss*	Consumption Grams/Mile	Percent Increase*
1970 A	12.3		228	
1970 A + 260 Lbs	12.1		232	
1973 A	10.9	9.9	257	10.8
1970 C	11.7		240	
1970 C + 440 Lbs	10.9		258	
1973 C	10.8	0.9	260	0.8
1970 D	12.0		234	
1970 D + 180 Lbs	11.9		236	
1973 D	10.6	10.9	265	12.3
1970 E	13.7		205	
1970 E + 320 Lbs	13.2		213	
1973 E	11.4	13.6	246	15.5
1970 F	14.2		198	
1970 F + 470 Lbs	13.8		203	
1973 F	11.6	16.0	242	19.2
1970 G	15.2		185	
1970 G + 80 Lbs	15.1		186	
1973 G	13.9	8.0	202	8.6
Avg 1970	13.2		213	
Avg 1970 + 291 Lbs	12.8		219	
Avg 1973	11.5	10.2	244	11.4

* At equal vehicle weight

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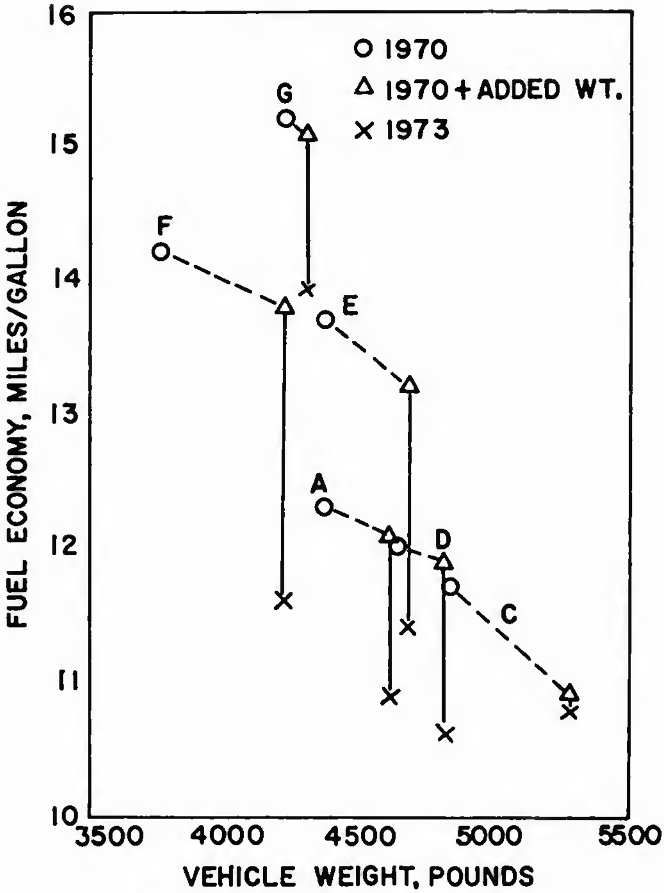


Fig. 2 – Fuel Economy Measured on Urban-Suburban Road Course of 1970 Vehicles, 1970 Vehicles with Enough Added Weight to Equal 1973 Vehicles, and 1973 Vehicles.

COMPARISON OF DU PONT AND EPA DATA

Another source of data showing the effect of emission control systems on fuel consumption is an EPA report (Reference 2). These fuel economy data are believed to have been calculated from carbon monoxide and carbon dioxide measurements made during the 1972 CVS Federal emission test procedure. More accurate results would have been obtained if allowance had been made for the hydrocarbons emitted -- this is particularly true for the pre-emission control cars which emitted substantially higher hydrocarbon levels than the 1970 and 1973 cars. The data from Table I of Reference 2 are illustrated graphically in the upper part of Figure 3 and the data corrected for hydrocarbon emissions are shown in the lower part of Figure 3. The fuel economies for the model years 1964 through 1967 were averaged to give representative fuel economies for the model years immediately prior to the institution of Federal exhaust emission controls in 1968. Also shown are the fuel economy data for the years 1970 and 1973. In Reference 2 the EPA averaged the data for all vehicle weights and concluded there were no significant differences between 1970 and 1973 vehicles other than a weight effect. However, there are significant differences in the fuel economies of the 1970 and 1973 vehicles when compared with the pre-controlled vehicles at all vehicle weights above 3500 pounds. In our opinion, the scatter in the data for vehicle weights below 3500 pounds precludes any conclusion as to the effect of model year on fuel economy for these lighter cars. This scatter may be due to the lack of a sufficient number of data points for these lighter weight vehicles and the wide differences in the types of vehicles represented. Above 3500 pounds, most of the vehicles are conventional U.S., standard size sedans equipped with relatively large displacement engines and automatic transmissions.

Du Pont data showing a fuel consumption increase of 11.4 percent from 1970 to 1973 for a nominal 4500 pound vehicle appear to be in reasonably good agreement with the EPA data. Fuel consumption data from the EPA study obtained from the faired curves corrected for hydrocarbon emissions shown in Figure 3 are given in Table X. Also shown are data from the Du Pont road test at a vehicle weight of 4653 pounds which was the average weight of the 1973 test fleet. The fuel consumption of the EPA's 1973 vehicles compared with the 1970 vehicles increased from just under 4 percent for the 3500 pound vehicles to more than 9 percent for the 5500 pound vehicles. The somewhat lower fuel consumption for the vehicles tested by Du Pont versus those tested by the EPA may be due to differences in the test cycle. As shown in Figure 4, the Du Pont Urban-Suburban test course includes substantially more steady speed operation than the 1972 CVS procedure used by the EPA.

The EPA data corrected for hydrocarbon emissions comparing the 1973 vehicles with the pre-emission control 1964 to 1967 vehicles are shown in Table XI. Fuel consumption increased from 7 to 20 percent dependent on vehicle weight. These data illustrate the effect of reduced compression ratios and emission control systems on fuel consumption because the comparisons are made at equal weight.

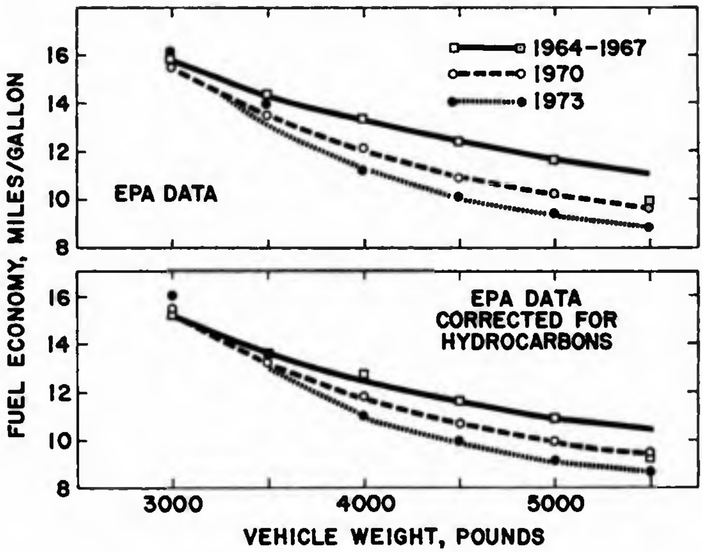


Fig. 3 — Fuel Economy of 1964 to 1973 Vehicles Calculated from Emission Test Results by the EPA.

Table X

Effect of Emission Controls and Compression Ratio Reduction on Fuel Consumption, 1970 to 1973

Analysis of EPA Report
Corrected for Unburned Hydrocarbons

	Fuel Usage					
	Economy Miles/Gal		Percent	Consumption Grams/Mile		Percent
Weight, Lbs	1970	1973	Loss	1970	1973	Increase
3,500	13.2	12.7	3.7	213	221	3.8
4,000	11.7	11.0	6.0	240	255	6.2
4,500	10.6	9.9	6.6	265	283	6.8
4,653*	12.8	11.5	10.2	219	244	11.4
5,000	9.9	9.1	8.1	283	308	8.8
5,500	9.4	8.6	8.5	298	326	9.4

* Du Pont road tests, with 1970 cars tested at equal weight of 1973 fleet.

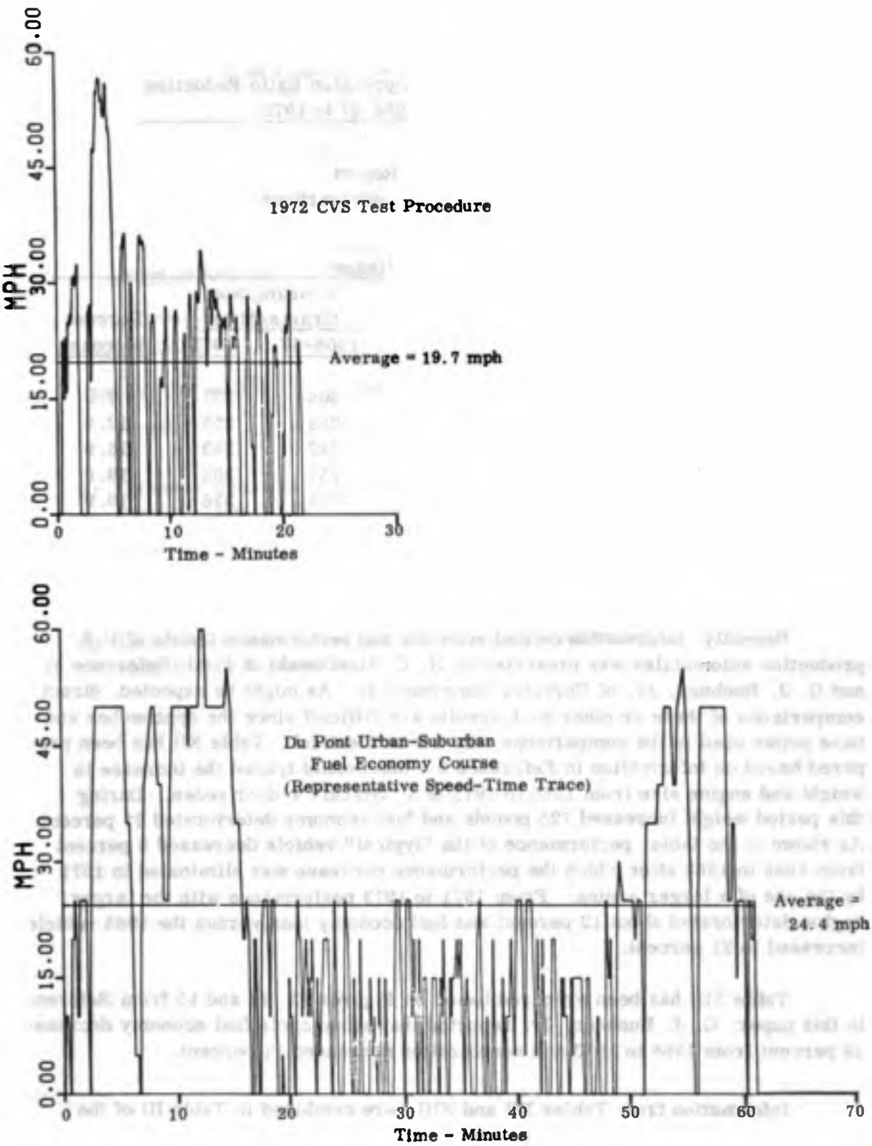


Fig. 4 – Speed Versus Time for 1972 CVS Procedure and Du Pont Urban-Suburban Fuel Economy Course.

Table XI

Effect of Emission Controls and Compression Ratio Reduction on Fuel Consumption, 1964-67 to 1973

Analysis of EPA Report
Corrected for Unburned Hydrocarbons

	Fuel Usage					
	Economy Miles/Gal		Percent	Consumption Grams/Mile		Percent
Weight, Lbs	1964-67	1973	Loss	1964-67	1973	Increase
3,500	13.6	12.7	6.6	206	221	7.3
4,000	12.4	11.0	11.3	226	255	12.8
4,500	11.6	9.9	14.7	242	283	16.9
5,000	10.9	9.1	16.5	257	308	19.8
5,500	10.3	8.6	16.5	272	326	19.9

COMPARISON OF DU PONT/EPA DATA WITH FORD AND CHRYSLER DATA

Recently, information on fuel economy and performance trends of U.S. production automobiles was presented by H. C. MacDonald of Ford (Reference 3) and G. J. Huebner, Jr. of Chrysler (Reference 4). As might be expected, direct comparisons of these or other such results are difficult since the approaches and base points used in the comparisons may not be identical. Table XII has been prepared based on information in Reference 3. MacDonald traced the increase in weight and engine size from 1965 to 1973 of a "typical" 4-door sedan. During this period weight increased 725 pounds and fuel economy deteriorated 21 percent. As shown in the table, performance of the "typical" vehicle decreased 8 percent from 1965 to 1968 after which the performance decrease was eliminated in 1971 by the use of a larger engine. From 1971 to 1973 performance with the larger engine deteriorated about 12 percent and fuel economy loss versus the 1965 vehicle increased to 21 percent.

Table XIII has been prepared based on Figures 13, 14 and 15 from Reference 4. In this paper, G. J. Huebner, Jr. reported that urban cycle fuel economy decreased 19 percent from 1968 to 1973 and acceleration decreased 11 percent.

Information from Tables XII and XIII were combined in Table III of the Appendix with information from the Cantwell, et al paper (Reference 1). Although direct comparisons cannot be made in all cases, it appears that the three sources are reasonably consistent.

Table XII

Fuel Consumption and Performance Trends
of "Typical" Ford Standard Size,
Four-Door Sedan

From SAE Paper 730517[1]

Year	Notes on Vehicle	Weight Pounds	Performance Loss, %[2]	Approximate Fuel Economy City/Suburban mpg	Approximate Fuel Economy City/Suburban Loss %	Approximate Fuel Consumption Increase, %
1965	"Small" V-8	3550	-	15	-	-
1968	"Small" V-8	3750	8	14.5	8	8
1971	350 cid V-8 plus[3]	4150	-	<13	15	17
1973	(4)	4275	12	12	21	26

(1) "Effect of Emission Controls on Energy Requirements," Harold C. MacDonald - Available in SAE Special Publication SP-383.

(2) Acceleration Time 0-60 mph.

(3) Also includes air conditioning, engine modified to run on 91 octane gasoline; safety and damageability standards met.

(4) Emission control system includes exhaust gas recirculation; 5 mph bumpers provided.

Table XIII

Fuel Consumption and Performance Trends of "3600 Pound" Chrysler Car

From SAE Paper 730518[1]

Year	Performance Loss, %[2]	Urban Cycle Fuel Usage: Economy Loss, %	Urban Cycle Fuel Usage: Consumption Increase, %
Overall Effect of Weight Increase and Emission Controls (Figure 13)			
1968-1973	11	19	24
Effect of 11 Percent Weight Increase (Figure 15)			
1968-1973	9	4	4
Effect of Emission Controls (Figure 14)			
1968-1973	2	15	18
1972-1973	1	10	11
Effect of 10 Percent Engine Displacement Increase (Figure 4)			
-	(12)-Gain	2	2

(1) "General Factors Affecting Vehicle Fuel Requirements," George J. Huebner, Jr. - Available in SAE Special Publication SP-383.

(2) Acceleration Time 0-60 mph.

ALLOCATION OF FUEL CONSUMPTION INCREASE TO VARIOUS FACTORS

The increase in fuel consumption of 25 percent from 1967 to 1973 cars is the result of a number of factors of which the most important appear to be increasing vehicle weight and decreasing engine compression ratio. Table XIV summarizes an attempt to allocate the effect of some of the changes that have taken place based on the information set forth in this report. The effect of compression ratio reduction has been taken from literature sources. Three references are given; many others might have been chosen.

Table XIV

Estimated Effects of Changes in Standard Size 1967 to 1973 Automobiles on Fuel Consumption and Performance

	Approximate Fuel Consumption Increase, %	Approximate Acceleration Time (0-60 mph) Increase, %	Reference
Weight Increase (~10% - 400 lb)	7	12-20	Tables IX, A-III
Engine Size Increase (~16% - 50 cid)	3	(10)	Reference 4
Tires and Suspension	(2)	(1)	Reference 4
Aerodynamic Drag	?	?	Reference 4
Transmission, Others	?	?	Reference 4
Compression Ratio Reduction (1.1 unit)	8	7	Reference 4, 8, 9
Emission Control Measures	9	3	A-III by difference
Total	25	12	A-III

The efficiency loss was manifested in slower acceleration time as well as in increased fuel consumption. If the acceleration time had been held constant, the total efficiency loss expressed in terms of fuel consumption increase would have exceeded 25 percent and would be roughly 32 percent. Conversion of 12 percent acceleration time increase to 7 percent fuel consumption increase is based on a study of compression ratio effects by F. W. Kavanagh, et al (Reference 9). In that study, compression ratio of a test car was varied between 12:1 and 9:1, and fuel economy was held constant by using a lower rear axle ratio at the lower compression ratio. Thus the efficiency decrease was manifested only in slower acceleration time. The 0 to 60 mph acceleration time was 8.0 at 12:1 and 9.8 at 9:1, an increase of 23 percent. In the same study, when a higher axle ratio was used at low compression ratio to hold performance constant, the fuel consumption increased 13 percent. Taking those results, and equating a 23 percent increase in acceleration time to a 13% increase in fuel consumption, the 12 percent increase in acceleration time from 1967 to 1973 would be equivalent to 7 percent fuel consumption increase.

$$(12\%)\ \frac{(13\%)}{(23\%)} = 7\%$$

It follows, therefore, that increasing compression ratio would represent an effective route for improving both performance and decreasing fuel consumption. In this connection it may be well to recall the work of Oberdorfer (Reference 10) and Felt and Krause (Reference 11) in which it was shown that increasing compression ratio in the range of 8 to 10:1 reduced hydrocarbon and carbon monoxide emissions on a mass basis with little if any effect on nitrogen oxides. These effects are shown in Figure 5 which is based on the work of Oberdorfer.

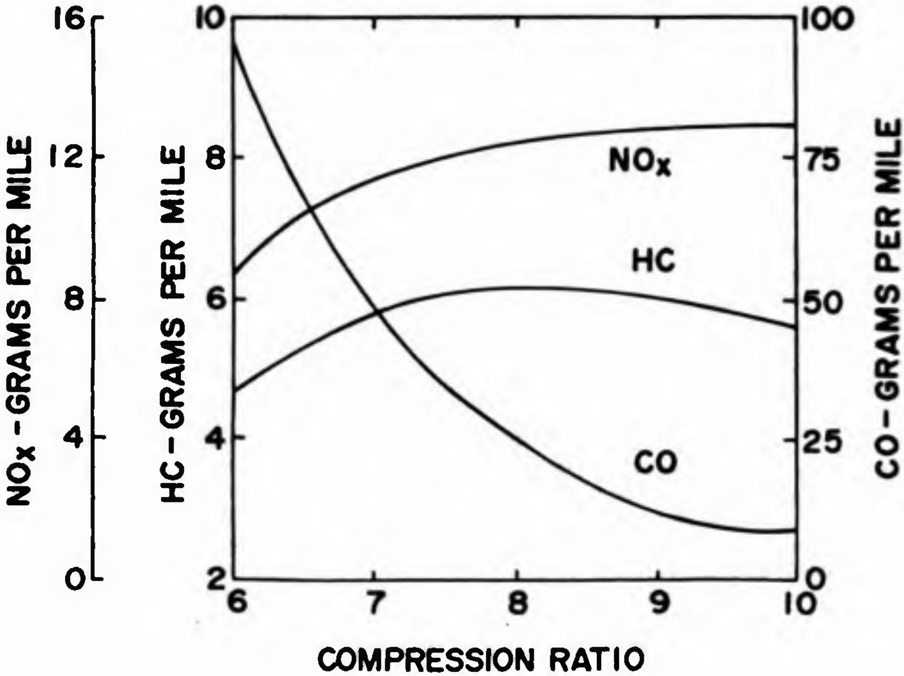
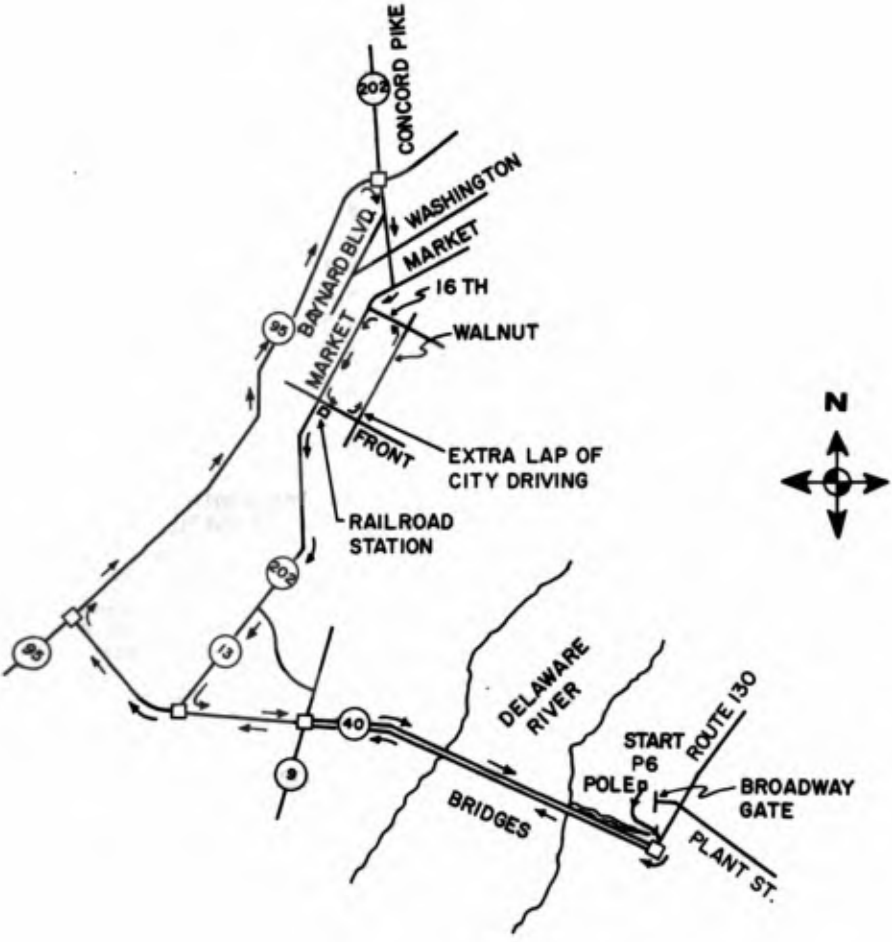


Fig. 5 – Effect of Compression Ratio on Exhaust Emission Levels at Equivalent Vehicle Driveability.

WEBettoney/et al/ap
June 1973

APPENDIX
Figure 1



Urban-Suburban Fuel Consumption Course.

APPENDIX
Table I and Table II

Table I

Compression Ratio of Cars Used in Program

Manufacturer's Published Ratios

Car Make	Model Year 1970	1971	1972	1973
A	9.0	8.5	8.5	8.5
C	10.0	8.5	8.5	8.5
D	10.0	8.2	8.2	8.0
E	9.5	9.0	8.5	8.6
F	9.5	9.0	8.5	8.0
G	8.8	8.6	8.6	8.6
Average	9.5	8.6	8.5	8.4
Weighted CRC Average*	9.4	8.7	8.6	-

* Based on analysis of data in CRC Octane Number Requirement Surveys for 1970, 1971, and 1972 (References 5, 6 and 7).

Table II

Measured Weight of Cars Used in Program

Weight Determined With Full Fuel Tank
and an Allowance for Driver and Equipment of 240 Pounds

Car Make	Model Year 1970	1971	1972	1973
A	4,350	4,470	4,520	4,610
C	4,840	5,050	5,070	5,280
D	4,640	4,690	4,660	4,820
E	4,360	4,400	4,450	4,680
F	3,760	3,600	4,110	4,230
G	4,220	4,210	4,220	4,300
Average	4,362	4,403	4,505	4,653

APPENDIX
Table III

Comparison of Fuel Consumption and Performance Trends of Standard Size Vehicles
as Reported by Ford - Chrysler - Du Pont - Du Pont/EPA
Pre-Emission Control to 1973 Model Cars

	Ford(1) 1965-73	Chrysler(2) 1968-73	Du Pont(3) 1970-73	Du Pont/EPA(3) 1964/67-73
Weight Increase				
Pounds	725	-	291	0
Percent	20	11	7	0
Performance Loss Due to Weight Increase C.R. Decrease and Emission Controls, %	12-20	11	10-21	-
Performance Loss Due to C.R. Decrease and Emission Controls, %	-	2	-	-
Fuel Economy Loss Due to Weight Increase C.R. Decrease and Emission Controls, %	21	19	13	-
Fuel Economy Loss Due to C.R. Decrease and Emission Controls, %	-	15	9	15
Fuel Consumption Increase Due to Weight Increase C.R. Decrease and Emission Controls, %	26	24	16	-
Fuel Consumption Increase Due to C.R. Decrease and Emission Controls, %	-	18	10	17

(1) "Effect of Emission Controls on Energy Requirements," Harold C. MacDonald - Available in SAE Special Publication SP-383.

(2) "General Factors Affecting Vehicle Fuel Requirements," George J. Huebner, Jr. - Available in SAE Special Publication SP-383.

(3) "A Total Vehicle Emission Control System," E.N. Cantwell, W.E. Bettoney, and J. M. Pierrard - API Division of Refining Meeting, Philadelphia - May 15, 1973.

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2. "Fuel Economy and Emission Control," U.S. Environmental Protection Agency, Office of Air and Water Programs, Mobile Source Pollution Control Program, November 1972.

3. MacDonald, Harold C., "Fuel Consumption Trends in Today's Vehicles," 1973 SAE National Automobile Engineering Meeting, May 15, 1973, Detroit, Michigan.

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11. Felt, A.E. and Krause, S.R., "Effects of Compression Ratio Changes on Exhaust Emissions," - Presented at SAE National Combined Fuels and Lubricants, Powerplant and Truck Meetings, October 26-29, 1971, St. Louis.

Mr. ROGERS. What would be the penalty if you only go to the 91 octane, rather than the 100 octane?

Would it be as great as six?

The companies said 1 percent.

Mr. BLANCHARD. Well, that is my point about General Motors, Mr. Chairman.

Mr. ROGERS. I am talking about Mobil and the other oil companies.

Mr. BLANCHARD. Well, I am talking about General Motors. That is what they have already done. They had done when I testified before this committee and screamed bloody murder 4 years ago, when Mr. Cole announced his decision. That is, they decided then, ahead of time, before they needed to do it and before anybody was thinking about putting a catalyst, was to reduce the compression ratio down far enough to soak the fuel economy for the past 3 years. And so, they could say, this car will use a 91 octane gas, even though there is no point in using a 91 octane gas. That is why your constituents are saying to you day in, day out today, why in the world am I taking all this loss on my car?

After you have done that for 3 years to get ready for the catalyst, then when you put the catalyst on it is meaningless to say how much you are going to save now. The question is, how much are you going to save or lose versus where we were before you started reducing the compression ratio in the first place.

Mr. ROGERS. Yes, but would you not agree that the lower compression ratio only resulted in about a 2-percent loss?

Mr. BLANCHARD. No, sir. No, sir.

Mr. ROGERS. What about the weight of the car?

Mr. BLANCHARD. What about it?

Lead saves 6 percent of whatever fuel it takes you to run air conditioning, or a heavy car, a little car, a medium car, any amount of fuel you want to use to run it.

Mr. ROGERS. Yes, but I am not sure that you single out and say that only changing the compression is what brought this about. Making big cars does it.

Mr. BLANCHARD. All I am saying is, the compression ratio reduction reduced it that much. Now, however much air conditioning you put on it, that is extra. If you want air conditioning, that is going to cost you.

Mr. ROGERS. Sure, air conditioning, the weight of the car——

Mr. BLANCHARD. Right, all of that.

Mr. ROGERS. The automatic transmission.

Mr. BLANCHARD. Right, all of that is going to waste fuel and I have no patience with it. We should not waste fuel, but whatever you waste this lead saves 6 percent of it.

Mr. ROGERS. Now what I am saying, now that we are out of that——

Mr. BLANCHARD. All right.

Mr. ROGERS. What about the 1-percent fuel penalty for making 91 octane gas nonleaded?

Do you agree with that statement?

Mr. BLANCHARD. I am not sure I understand the statement. I am sorry.

Mr. ROGERS. What I am trying to say is, the oil companies said there would be a fuel penalty of 1 percent to bring about unleaded gasoline at 91 octane.

Mr. BLANCHARD. All right, can I answer that this way?

Mr. ROGERS. Certainly.

Mr. BLANCHARD. What I tried to say a while ago—not I tried to say, all the testimony today was that the pool is 88½. That is what it is today, average all across the board if you do not do anything to it.

Now all they are saying is, to get that pool at 88½ up to 91, which Mr. Cole says it takes to run his car, which we do not agree satisfies it—but nevertheless, if you are going to make 91, I do not disagree that that takes 1 to 2 percent was what they said.

Mr. ROGERS. Well, this was what I wanted to know.

Mr. BLANCHARD. Yes; but when you get it to the 91, you have already wasted, you have already taken the penalty of coming down on your compression ratio far enough to let that 91 satisfy that engine. That is the penalty we took 3 years early.

Mr. ROGERS. Yes; but it all is taken on the idea that we want to clean up the air.

Mr. BLANCHARD. OK, but what——

Mr. ROGERS. Now, if we want to wipe that out——

Mr. BLANCHARD. No. No; I am not suggesting wiping it out. I am only suggesting what Mr. Satterfield's amendment is, that while we do not have enough gas to run the cars we have got, then we had better start holding where we are, not going backward. I am not suggesting you go backward. I am suggesting that you hold your present standards, which as the old cars go off the road will still continue to improve dramatically, and that will save fuel oil to keep you warm, or half the barrel to make some gasoline to run the cars that you do make.

Mr. ROGERS. Except that the contrary testimony is that the fuel loss in 1974 can be reduced with the catalytic converter 13 percent, anywhere from 6 to 13. Now, the oil companies said you would have a 3-percent reduction.

Mr. BLANCHARD. A 3-percent reduction or improvement?

Mr. ROGERS. Of loss.

Mr. BLANCHARD. All right, but this is on top of the loss that you have already taken up, 20 percent. You can get that back.

Mr. ROGERS. I understand, but you are recommending the 1974, which has a built-in penalty.

Mr. BLANCHARD. But it does not have to have the penalty. They only have the penalty in it to get ready for the catalyst.

Mr. ROGERS. Well, if you must maintain a level, I think that is admitted as a penalty already. It exists in the 1974 standard, you see.

Mr. BLANCHARD. Mr. Chairman, could I make one statement on that and then I will stop?

I realize I am being argumentative, and I apologize.

Mr. ROGERS. No; this is what we need.

Mr. BLANCHARD. All we are saying, and we said it 4 years ago to you. We said that Ethyl had a car, but in addition there are 50 other people that have got a car. That is, a car that can meet the 1974 standards without any of this loss of economy. The difference has been, it cannot meet the 1975, 1976, and 1977, so to speak, standards. As you get tougher than the 1974, our car falls by the wayside, other cars fall by the wayside. But you can meet the 1974 standards with an efficient automobile that does not require this fuel penalty, is our point.

Now, when you go beyond this we admit you have got deep trouble. You do start losing efficiency, which you can make up by putting a catalyst, and then losing your efficiency by having to have lead-free gas, whichever way is the tradeoff.

Mr. SATTERFIELD. Mr. Chairman, may I ask one additional question?

Mr. ROGERS. Yes.

Mr. SATTERFIELD. We talked about the percentage of gain with the catalytic converter, and I want to go back to the automobile I drive, and I am going to talk about what I know and ask you, if I am correct. I know that in my automobile I have dropped from a little less than 15 miles a gallon in a 1971 model to 10 in a 1973 model. Now, if I have that same model and put a catalytic device in it, I am going to get—let us say as much as a 13-percent increase; 13 percent of 10 gallons is 1.3 gallons. I am only going to increase my economy up to 11.3 gallons, not anywhere near approaching the original 15.

Is that not correct?

Mr. BLANCHARD. That is correct. But what I would suggest you gentlemen do is, if you ever get a chance to ask Mr. Cole the question, you find out whether he is saying that you will get a 13-percent improvement on your automobile when you put the catalyst on an identical car, or is he throwing in a whole bunch of small cars that Europe has convinced us we ought to buy, to average them all in to talk about his fuel economy. I am not sure which he is talking about.

Mr. SATTERFIELD. I understand that. But what you are saying further is that 6 percent of that penalty came about because we have reduced the compression ratio and lowered the lead in gasoline, which was not necessary to meet the 1973 or the 1974 standards?

Mr. BLANCHARD. Correct.

Mr. SATTERFIELD. Thank you, sir.

Mr. ROGERS. Thank you so much for your presence. We again apologize for keeping you gentlemen so late.

Mr. BLANCHARD. Thank you for your patience in waiting until 5 minutes before 7 to hear us. We appreciate it.

Mr. BUTLER. Thank you.

Mr. ROGERS. You have been most helpful to the committee.

The committee stands adjourned until 2 o'clock tomorrow afternoon.

[Whereupon, at 6:55 p.m., the subcommittee adjourned to reconvene at 2 p.m., Tuesday, December 4, 1973.]

NEW MOTOR VEHICLE EMISSION STANDARDS AND FUEL ECONOMY

TUESDAY, DECEMBER 4, 1973

HOUSE OF REPRESENTATIVES,
SUBCOMMITTEE ON PUBLIC HEALTH AND ENVIRONMENT,
COMMITTEE ON INTERSTATE AND FOREIGN COMMERCE,
Washington, D.C.

The subcommittee met at 2 p.m., pursuant to notice, in room 2322, Rayburn House Office Building, Hon. Paul G. Rogers, chairman, presiding.

Mr. ROGERS. The subcommittee will come to order please.

We are continuing our hearings regarding the Clean Air Act and its relation to the energy crisis. And our first witness this afternoon is Dr. Edward E. David, executive vice president of the Research, Development & Planning, Gould, Inc.

The committee welcomes you, Dr. David, and we appreciate your being here. As you know, the committee has asked witnesses to have a 5-minute statement, and then be subject to questioning by the committee. And if you could proceed in that timeframe, it would be helpful.

STATEMENT OF DR. EDWARD E. DAVID, EXECUTIVE VICE PRESIDENT, RESEARCH, DEVELOPMENT AND PLANNING, GOULD, INC.; ACCOMPANIED BY DR. ROBERT FEDOR, DIRECTOR, EMISSIONS CONTROL, GOULD, INC.

Dr. DAVID. I will try to run through this in a hurry, Mr. Chairman.

Mr. ROGERS. Thank you.

Dr. DAVID. On my right is Dr. Robert Fedor, who is in charge of Gould. Inc.'s research and development program on emissions control.

Mr. ROGERS. Dr. Fedor, welcome you.

Dr. DAVID. As you know, I am vice president, director of research and planning for Gould. As you know, I previously testified before the committee in September, and I reported on our progress in making——

Mr. ROGERS. Could you speak just a little louder?

Are the mikes connected?

No mikes. I am sorry, sir. If you could speak a little louder?

Dr. DAVID. As you know, I testified previously in September before this committee on the progress that our company has been making on a reliable base-metal catlyst for reducing the exides of nitrogen in automobile exhausts to the 1977 statutory limit. I would like to express today Gould's position on the amendment to the Clean Air Act, which would freeze the 1975 emission standards through the 1977 auto year.

Let me begin by saying that I think stable statutory requirements must be fixed as quickly as possible. Like the automobile manufacturers, we also need adequate leadtime.

But the statutory requirements for NO_x emission controls must be based on a careful and thorough examination of all relevant factors, and not on an "amendment of the day" which, as far as I can see, is unsupported and unaccompanied by any substantial evidence. The relevant factors which the Congress ought to consider include the health effects of NO_x and the other automobile-related pollutants, the fuel benefits and penalties associated with the various methods of controlling those pollutants, and the other costs and benefits associated with those methods of control.

These are complex questions. And we believe that they can be answered fairly and correctly only after this committee has had an opportunity to examine the latest EPA recommendation on NO_x control, the most recent Japanese and American health studies, and the report from the National Academy of Sciences on its current investigations.

We urge this committee to take the time to examine these reports, studies, and recommendations with the utmost care, for there are likely to be serious conflicts between them, and serious doubts have already arisen about one of them.

For example, we have serious reservations regarding the EPA conclusions, specifically with regard to the health effects of NO_x. Gould itself is not expert in health effects of NO_x and other pollutants. But we have retained outside consultants to review available worldwide toxicological and epidemiological studies on NO_x. According to these consultants, there is doubt that the current ambient air quality standards for NO_x are strict enough to protect the public health.

Now that I have summarized the important issues which this amendment would ignore, I would like to review the status of our NO_x control technology in light of the energy crisis. We feel the technology for strict NO_x control does exist, and achieving strict NO_x control need not conflict with energy conservation.

First, with regard to the technology, when it is used in a properly engineered system with correct carburetion, Gould's catalyst is capable of achieving NO_x conversion of well over 95 percent. In tests to date, emission levels of less than 0.2 gram/mile are not unusual, even after several thousand miles. These results have been verified at EPA's facility in Ann Arbor on a Ford Torino with a dual catalyst system using Gould NO_x catalyst. These results were 0.13 gram/mile NO_x, 0.27 gram/mile HC, and 2.18 gram/mile CO.

The overall performance of the Gould catalyst has been demonstrated in road tests totaling over 250,000 miles. For the first few thousand miles, conversion efficiencies of well over 95 percent are typical, giving emission levels between 0.1 and 0.2 gram/mile on standard size U.S. cars. As mileage accumulates, the catalyst activity decreases until at 25,000 miles, there is around 90-percent activity, giving emission levels between 0.35 and 0.55 gram/mile. In addition to its NO_x capability, the Gould catalyst is entirely compatible with commercially available oxidation catalysts.

What is the situation on fuel economy? The noncatalyst emission controls on today's cars have led to a substantial fuel penalty as compared to completely uncontrolled cars. There have been several estimates of the severity of this penalty. The most reliable figures we have indicate it might be as high as 14 percent. The use of catalysts for emission control can recover a substantial part of this penalty.

Let me try to be specific. A system employing catalysts can be optimized to meet statutory 1977 standards and give better fuel economy than both current models and the improved 1975 models, which only meet interim emission standards. In 1975, it appears that cars with an oxidation catalyst for hydrocarbon and carbon monoxide control will achieve an average of only 6 percent worse fuel penalty than an uncontrolled car. Thus, there is an 8-percent improvement over 1973 vehicles.

For 1977 models, which will achieve stricter hydrocarbon and carbon monoxide control and strict NO_x control, it appears that use of a dual catalyst system with the elimination of exhaust gas recirculation (EGR) could result in a 2- to 6-percent improvement over 1973. Along with the use of a dual catalyst system and the elimination of EGR, additional system modifications such as belted radial tires, higher compression engines, and improved carburetion and startup techniques, could result in fuel economy slightly better than the 1975 projections.

This means that with known technology, the Nation can achieve existing emission control goals for the protection of our health, and still conserve our energy resources.

Let me conclude, Mr. Chairman, by saying that we as a Nation are traditionally sensitive, perhaps overly sensitive, to the problems facing us, particularly when those problems arise suddenly and loom large. But if we stop and thoughtfully gain perspective on our situation today, we see that energy supply, energy conservation, and environmental preservation all equally support the lifestyle to which we aspire, just as three legs support a stool. Emergencies always will arise, but responding to those emergencies should not entail sacrificing one of those supports. If we do, the stool collapses. If science and technology are used to the fullest extent possible, those three supports need not be in conflict with one another, but can be equal partners in realizing both an adequate quality of life and a high standard of living.

I will be happy to answer any question you might have.

Mr. ROGERS. Thank you very much, Dr. David. We will question under the 5-minute rule, because we have a number of witnesses this afternoon.

Mr. Satterfield.

Mr. SATTERFIELD. Thank you, Mr. Chairman.

Dr. David, with reference to the statement that a catalyst has been tested 250,000 miles. You say the first few thousand miles is well over 95 percent efficient; at 25,000, that drops to about 90 percent.

What happens after 25,000 miles?

Dr. DAVID. After 25,000 miles, Mr. Satterfield, the activity continues to decrease. And the catalyst, in ordinary operation, would have to be replaced after 25,000 miles.

Mr. SATTERFIELD. So this talk that we heard 3 years ago, that a catalyst ought to be perfected for 50,000 miles minimum, no longer pertains?

Dr. DAVID. I do not think we have ever said as a company that we could obtain a 50,000-mile-NO_x-reduction catalyst. I believe there was some talk of that with respect to oxidation catalysts, but I am not certain.

Mr. SATTERFIELD. What will be the cost of your catalyst?

Dr. DAVID. We project that the net cost, including credit for taking off the exhaust gas recirculation, would be around $60 per car. That is the sticker price.

Mr. SATTERFIELD. And then if you were going to replace it, it would be $60 plus the cost of the unit?

Dr. DAVID. No; it would be somewhat less than that. And I would like to ask Dr. Fedor what his current estimate of the replacement cost would be.

Dr. FEDOR. No more than $40.

Mr. SATTERFIELD. Plus labor?

Dr. FEDOR. Perhaps.

Mr. SATTERFIELD. You speak about an 8-percent improvement over 1973 models, even in the worst cars, but you also talk about the fact that the penalties in the 1974 models right now are 14 percent.

Dr. DAVID. We have looked at a great deal of data which is available to the general public. Our conclusion on looking at all of it is that 14 percent is approximately the current penalty. There are, of course, deviations depending on car size. The 14 percent is for standard size U.S. cars, Mr. Satterfield.

Mr. SATTERFIELD. And how much do you say you can pick up in economy if you put a catalyst on?

Dr. DAVID. Our estimate is 8 percent over 1973.

Mr. SATTERFIELD. Well, all right.

And then you say that in the 1977 model years, that this would drop down to a further 4 or 6 percent.

Dr. DAVID. The 2- to 6-percent improvement over 1973 is what we measured with today's technology in the ignition and fuel system. We believe that if the highest technology fuel and ignition systems are used, including a compression increase in these automobiles, that the 1977 mileage could be approximately the same or slightly better than 1975.

Mr. SATTERFIELD. You say increase in the compression——

Dr. DAVID. Yes.

Mr. SATTERFIELD. How would you go about doing that?

Dr. DAVID. I think you ought to ask the automobile companies exactly how they——

Mr. SATTERFIELD. You make the statement you do not know how it is going to be done?

Dr. DAVID. Well, I know how you can increase the compression in an automobile. And I do not think you want a technical explanation of that. There is no reason that that could not be done, Mr. Satterfield.

Mr. SATTERFIELD. Would not it require higher octane gasoline?

Dr. DAVID. Yes, it would. It would require 95–96 octane gas, which according to the oil companies' projections—and this is information that is known to the general public—would produce maximum miles of travel per barrel of oil.

Mr. SATTERFIELD. Does your catalyst run on leaded gasoline?

Dr. DAVID. It can, but as I told you in the previous hearings, our catalyst is part of a system which would not use leaded gasoline.

Mr. SATTERFIELD. Were you aware of the fact that the only way you could get 94 octane would be to add lead to the gasoline?

Dr. DAVID. That, according to our information, is not so, Mr. Satterfield.

Mr. SATTERFIELD. Not so?

Well, let me ask you one other question. Has any automobile manufacturer contracted with you to employ your catalyst in their vehicle?

Dr. DAVID. I am sorry. I did not get the question.

Mr. SATTERFIELD. Has any manufacturer contracted with you or indicated he is going to employ your catalyst?

Dr. DAVID. We have no production contracts at the present time.

Mr. SATTERFIELD. No contracts.

Thank you.

Mr. ROGERS. Dr. Carter.

Mr. CARTER. Thank you, Mr. Chairman.

Your catalyst is quite efficient, 95 percent efficient for 25,000 miles. Correct?

Dr. DAVID. Let me interrupt, Mr. Carter. No, it is not 95 percent efficient for 25,000 miles. It begins——

Mr. CARTER. I read that in your statement.

Dr. DAVID. It begins its operation at 95 percent, approximately, efficient, and over the 25,000 miles the activity decreases until at the end it is about 90 percent efficient. So that there is a decrease in conversion efficiency over the 25,000 miles, from about 95 to 90 percent.

Mr. CARTER. Thank you. It is a little clearer than your statement was.

Dr. DAVID. I am sorry.

Mr. CARTER. From 25,000 to 50,000 miles, there is a continued diminution in the effectiveness of your converter. Is that correct?

Dr. DAVID. That is correct, and the converter would have to be replaced at 25,000 miles. There is no doubt of that.

Mr. CARTER. It would go up to emitting as much as 0.55?

Dr. DAVID. At 25,000 miles, we estimate the emission at between 0.35 and 0.55 grams per mile.

Mr. CARTER. Yes.

Thank you so much. You say that a car, a 1975 model car fitted with your converter, will show an improvement in fuel consumption. That is, it will consume less by 8 percent than the 1973 model. Is that correct?

Dr. DAVID. No, sir. We have taken the automotive and EPA figures, and we would say that the 1975 models on the average will use 8 percent less fuel per mile than the 1973 models. If we did not advance automotive technology at all between 1975 and 1977, we would have a 2-percent improvement over 1973.

But we believe that, with improvements and using the maximum technology available, in 1977 one could get operation approximately equivalent to 1975, which is 8 percent over 1973.

Mr. CARTER. Now, you came back to the very same thing: 8 percent over 1973. This is what I had asked you really.

Now, suppose we had a car in 1971 that got 15 miles per gallon. In 1973 with the 15-percent penalty, it would get 12.75 miles per gallon. Is that correct?

Dr. DAVID. The 14-percent figure that we used is over an uncontrolled car, and the 1971's had some control on them.

Mr. CARTER. Well, I am using 15 percent. I think that is accepted by a great many anyway. You would have a penalty; you would get only 12.75 miles per gallon in the 1973 car versus the 1971.

Now, you would get an increase——

Dr. DAVID. Of 8 percent.

Mr. CARTER. Of 8 percent.

And still with that 8-percent increase, would your savings be equal to that, or would your miles per gallon equal the miles per gallon in 1971?

Dr. DAVID. Well, obviously not if you use the figures which you are using. However——

Mr. CARTER. If you use any other figures, you cannot do it. I mean any acceptable figures.

Dr. DAVID. Well, as we indicated, the penalty over an uncontrolled car, which is not 1971, but over an uncontrolled car would be something like 6 percent.

Now, the benefits you are getting for that 6-percent fuel penalty is a contribution to clean air.

Mr. CARTER. I certainly had hoped that we got clean air, but I still feel like we have got a greater loss in mileage than your figures would show, and your words indicate.

Mr. ROGERS. Thank you.

Mr. Hastings.

Mr. HASTINGS. Thank you, Mr. Chairman.

I am trying to find out what you were advising this committee to do as far as the standards are concerned. I have not seen where you really spell it out here. You tell us that we ought to set them up as quickly as possible.

Do you favor the Administration's proposal locking the 1975 standards for 1976–77, or do you favor leaving the standards alone as presently written in statute, or just exactly what do you favor?

Dr. DAVID. Mr. Hastings, Gould would favor leaving the standards as is.

Mr. HASTINGS. Without any changes whatsoever?

Dr. DAVID. Without any changes.

Mr. HASTINGS. Now, I have some difficulty, in talking to different people, manufacturers of automobiles and manufacturers of catalytic converters, and oil companies, in arriving at fuel economy problem along the lines; in 1975, where GM says that the 15-percent economy is going to be at variance.

I understand there could be a minor variance. Some other automobile manufacturers say a little bit differently, of course. We will get to those a little bit later on in the afternoon.

But when you go from 1975 to 1977, some charts show me that there is as much as a 30-percent decrease in efficiency, when you take a combination of the converter, and then the tuneup of the engine that probably will be required to meet the 1977 standards. But I do not think your statement reflected that exactly.

Dr. DAVID. No; it did not, Mr. Hastings. Our projections and our tests—these are not only projections, but mileage tests done with our cars and confirmed by independent groups—indicate that with today's technology in the ignition system and in the fuel system, that one would get a 2-percent credit in 1977 over 1973.

Mr. HASTINGS. Well, then at that point—I am a simple layman trying to figure out what is the best thing to do in the interests of everybody here.

Now, why is there such a discrepancy between what one automobile manufacturer will testify to in front of this committee, and what you are prepared to? And I am sure you are all interested in the same thing.

But why is there such a discrepancy?

Dr. DAVID. Well, I am not sure.

Mr. HASTINGS. I understand you are not sure. Everybody has a vested interest, and everybody in this room probably does. But we have the problem of trying to separate that all out, and do what we think is best.

Dr. DAVID. What I have tried to do in this testimony, Mr. Hastings, is to testify on the basis of the best data available to us, including our own tests, and to give you that information in as straightforward a way as I can. I cannot account for the discrepancies in testimony by other people.

I can merely say that if one uses the best technology that is available at a given time, that the fuel penalties that will result from automobile emissions controls ought to be very small. And the figure that we project is something like a 5- or 6-percent penalty in total over an uncontrolled car.

Mr. HASTINGS. How would you feel toward using the California interim standards, rather than the existing statutory standards?

Dr. DAVID. Well, I think there are very serious questions about health effects. That is really the issue on which this committee should judge the adequacy of the overall emission standards. Emission standards, of course, have to be related to ambient air standards and that to the health effects.

As I indicated in my testimony, we have retained consultants in the health area to advise us on this matter, and we believe there are serious health questions that would be raised if the ambient air quality standards were weakened.

Mr. HASTINGS. In other words, you would be opposed to that, preferring to stay with the statutory standards?

Dr. DAVID. Unless there were scientific information available that told us that the health effects were not a problem.

Mr. HASTINGS. All right.

Thank you.

Mr. ROGERS. Mr. Heinz.

Mr. HEINZ. Mr. Chairman, let me defer my questioning. I apologize for being late.

Mr. ROGERS. That is all right.

We will get to his testimony. I understood there was a car, a Matador, that had used your equipment, that has been tested. Are you aware of the results of that testing?

Dr. DAVID. Well, we have been informed of the results of that testing, Mr. Chairman.

Mr. ROGERS. I see.

Well, perhaps you could give us your comment on that for the record, rather than now.

[The following information was received for the record:]

COMMENTS REGARDING GOULD CATALYST USED ON DR. BALGORD'S TEST VEHICLE

In April, 1973 Gould provided Dr. Balgord with two GEM 67 catalysts typical of those provided to Detroit in spring-summer, 1973. Instructions on general system design especially preferred carburation were also provided. Tests on the New York State car were performed at Gould at 16 and 25,000 miles. In addition, we encouraged Dr. Balgord to have his car tested at the EPA in Ann Arbor to insure the objectivity of the test results.

We feel that the New York State test results are quite comparable to that of Gould's fleet tests which were reported to the EPA in July, 1973. Our own data varied from .39 to .60 gram per mile NO_x at 25,000 miles under a variety of mileage accumulation schedules. It is felt that this data reflects not only the capability of GEM to reduce NO_x but also indicates its compatibility with the oxidation catalyst to achieve stringent control of HC and CO as well.

In retrospect the New York State data demonstrates the rapid progress in NO_x control technology that has occurrd over the past few years. The status of this technology is comparable to that of oxidation catalysts at the May, 1972 EPA hearings. A that time only Englehard and Matthey Bishop displayed promising data. Because of the catalyst companies data the EPA upheld the stringent HC and CO standards and in effect forced the auto companies to perform the systems work required to refine the oxidation catalyst technology for mass utilization. In a similiar fashion aggressive pursuit of the system technology for reducing catalysts is now required prior to mass utilization.

Mr. ROGERS. I understand it is your testimony then that the standards should not be changed.

Dr. DAVID. This is correct, Mr. Chairman.

Mr. ROGERS. You think the emission standards are capable of being met?

Dr. DAVID. Yes, I do.

Mr. ROGERS. All right.

Thank you very much. We are grateful to you for being here.

There is a call to the House floor. The committee will recess for 5 minutes.

[Brief recess.]

Mr. ROGERS. The full committee will go into session as soon as the rule has been adopted on the next bill. I do not know how long that will take. We may have a number of minutes, half an hour, or an hour.

But in any event, I think we should get started with the automobile industry witnesses. We may have to have a postponement if we cannot finish before the full committee goes into session. until 5 this afternoon and finish up at 5. We hope we can do it before; but I think if we can proceed now, and if the industry witnesses would take your places at the table, I would be grateful.

Mr. Edward N. Cole, president of the General Motors Corp.; Mr. Herbert L. Misch, vice president, safety and environmental affairs of the Ford Motor Co.; Mr. Sydney L. Terry, vice president, environmental and safety relations, Chrysler Corp.; and anyone that you want to join you at the table. Just pull up some chairs behind you.

I am sorry that we will have to adjust to the full committee's schedule. We had not anticipated an afternoon session, but as you know, we are trying to get the energy bill out, so it will require an afternoon session.

You gentlemen may proceed however you desire. As I understand it, each would have a statement of approximately 5 minutes, and then we can get into questions and discussions.

Mr. SYMINGTON. Mr. Chairman, the statements will be made a part of the record.

Mr. ROGERS. Without objection, it will be made a part of the record. Mr. Misch, would you like to begin?

STATEMENTS OF HERBERT L. MISCH, VICE PRESIDENT, ENVIRONMENTAL AND SAFETY ENGINEERING STAFF, FORD MOTOR CO.; SYDNEY L. TERRY, VICE PRESIDENT, SAFETY AND ENVIRONMENTAL RELATIONS, CHRYSLER CORP.; ACCOMPANIED BY VICTOR TOMLINSON, COUNSEL; AND CHARLES HEINEN, DIRECTOR, VEHICLE EMISSIONS; AND EDWARD N. COLE, PRESIDENT, GENERAL MOTORS CORP.

Mr. MISCH. Yes, Mr. Chairman. May I request that my full statement be filed as a part of the record?

Mr. ROGERS. Without objection, it will be made a part of the record.

Mr. MISCH. I do have a summary prepared in the interest of time. That summary has been handed out just so that you can follow me.

My name is Herbert L. Misch, vice president of environmental and safety engineering staff of Ford Motor Co.

I have previously testified in September before this committee in respect to our concern about catalyst durability and reliability, and I will not repeat that or the other points we made at the time of our last appearance. The aggravated nature of the gasoline shortage which has become apparent since September does, however, add several new points of view which deserve to be a factor in the determination of Congress on this issue.

For example, a theoretical improvement of only slightly more than 1 percent in total automobile emissions would result in 1975 by following the vehicle emission standards now specified by EPA for that year compared to carrying over our present 1974 requirements. However, if the gasoline shortage aomunts to 15 percent—and we have heard it will be at least that much—then vehicle emissions will obviously be reduced by that same 15 percent. On that basis, it is simply not realistic to say that a carryover of 1974 standards would result in a slowing up of environmental improvement. Therefore, it appears to me that this committee is not considering a decision which is for or against clean air. Instead, the issue is to decide what is most logical in respect to the energy crisis.

Second, we believe that gas shortages will increase the improper fueling of catalyst equipped cars. Several factors could lead to this situation. There will be a very limited demand for unleaded gasoline for some time because of the relatively small population of cars needing this fuel. By the fall of 1975, for example, fewer than 10 percent of all cars on the road will require unleaded gasoline. This low level of demand would create supply and distribution problems even in the best of times. Supplying outlying stations with unleaded gasoline, when the demand is low and general shortages prevail, would seem to pose more problems. In times of shortages and allocation of fuel, service stations and wholesale delivery facilities might be more lax in maintaining sterile unleaded gasoline which requires special and dedicated facilities in the various handling and delivery stages.

Possibly of greatest concern are those problems arising out of unleaded fuel shortages. The overall short supply of gasoline could lead to the indiscriminate use of leaded and unleaded fuel. For example, if a station runs out of unleaded gasoline, there may be more tendency to "force feed" catalyst cars with leaded gasoline. If a motorist with a catalyst-equipped car ran low on fuel or out of gas altogether, he probably would be happy to get any kind of gas he could—leaded or unleaded—rather than be stranded.

There has been a great deal of confusion about the effect the 1975 standards will have on fuel economy, particularly when catalysts are used. I have in my attachment A to my full statement a chart we previously submitted to the Senate Public Works Committee which shows an 8-percent difference in gasoline mileage between cars with and without catalysts while both are designed to meet present 1975 standards. The 1975 fuel economy with catalysts, however, is only 3 percent better than our 1974 models. We understand from testimony and data from oil companies that unleaded gasoline reduces the yield per barrel of crude oil. If so, we would have to conclude that the effects of our petroleum supplies from carrying over 1974 standards and meeting 1975 standards with catalysts would be equivalent.

In the other attachment to my statement, attachment B, we indicate the effect of fuel economy on Ford cars occurring as a result of imposing two different sets of emission standards beginning with the 1975 model year. Carrying the 1974 standards over for 2 years and adopting the California interim standards in 1977, as we recommend to the Senate Public Works Committee, will avoid the premature use of catalysts and actually result in a net fuel saving of 5 percent by 1977.

Let me turn to another point. Last week EPA recommended to Congress certain NO_x standards up through the 1990's. The EPA proposal would establish NO_x controls at 2 grams per mile but only up through 1981 when they would then be reduced to 1 gram per mile and then later be reduced to 0.4 gram per mile.

Ford Motor Co. already has told this committee that if the long-term NO_x standard is set at a minimum of 2 grams per mile and if all our developmental goals were achieved, the best we could do would be to convert one engine line to an alternate engine in 1977. However, we could not do even that if the EPA proposal is followed. We could not proceed. If we did, we would be part way through our conversion of facilities when we would be forced to stop conversion and probably abandon the new engine because it does not have the potential to meet a 1-gram standard in 1982.

To develop realistic development goals for our alternate engine research, we need congressional guidance on future NO_x requirements by the end of this year.

Early congressional direction is also required for the next few model years on all three vehicle emission standards. For example, we should know before the end of this year what changes will become law with respect to all standards for 1976. We start building 1976 precertification vehicles next spring and we need prototype parts now. We must make firm facilities commitments to our suppliers this month for emission control components for 1976 models. For these reasons, we urgently need immediate congressional direction. A delay until next year, as recommended to you by EPA yesterday, totally ignores the leadtime requirements of our business.

Let me summarize Ford Motor Co.'s position. We strongly urge that you consider carryover of the 1974 standards—primarily to avoid the use of unleaded fuel during the gasoline shortage—but also to avoid the risks associated with massive application of new catalyst technology.

We further request that you provide immediate direction for the NO_x levels you plan to establish for 1978 and beyond so that we can intelligently plan our alternate engine research. Finally, we ask for congressional direction on these vehicle emission standards this month so we can meet the urgent needs of preparing for production of 1976 models. Perhaps the best way to do this would be to amend the emergency energy bill now pending before the House Interstate and Foreign Commerce Committee, a bill which has already passed the U.S. Senate.

Thank you for this opportunity to present our views on these vital matters. We have tried to make it clear that we are convinced it would be counterproductive to alleviation of the energy shortage to do anything but carry over 1974 emission standards and continue the use of leaded fuel for the next few years.

[Testimony resumes on p. 187.]

[Mr. Misch's prepared statement follows:]

STATEMENT OF HERBERT L. MISCH, VICE PRESIDENT, ENVIRONMENTAL & SAFETY ENGINEERING STAFF, FORD MOTOR CO.

My name is Herbert L. Misch, Vice President, Environmental and Safety Engineering Staff, Ford Motor Company. I appreciate this opportunity to appear before you regarding the Clean Air Act.

You may recall that when I testified before this Committee in September, I recommended that Congress determine whether the 1974 motor vehicle emission standards should be continued in effect for an additional two years or whether the 1975 interim standards for passenger cars should be retained for a period of time. I indicated what we believe to be the advantages and disadvantages of each position but made no specific recommendation.

More recently, on November 5, I testified before the Senate Public Works Committee on the same subject and noted that the growing severity of the predictions of energy, petroleum and gasoline shortages argues strongly that Congress provide for the carryover of 1974 standards.

I have previously testified before this Committee in respect to our concern about catalyst durability and reliability and I will not repeat that and the other points we made at the time of our last appearance. The aggravated nature of the gasoline shortage which has become apparent since September does, however, add several new points of view which deserve to be a factor in the determination of Congress on this issue.

For example, the theoretical improvement of only slightly more than one percent in total automobile emissions would result in 1975 by following the vehicle emission standards now specified by EPA for that year compared to carrying over present requirements. However, if the gasoline shortage amounts to 15 percent, and we have heard it will be at least that much, then vehicle emissions will obviously be reduced by that same 15 percent. On that basis, it is simply not realistic to say that a carryover of 1975 standards would result in a slowing up of environmental improvement. The control levels applicable to 1974 models are substantial and auto caused air pollution will be reduced if we simpy replace older cars with these new vehicles meeting present standards. The fact that there will be significantly less fuel consumed by all vehicles during the next couple of years will accelerate the atmospheric clean up. Therefore, it appears to me that this Committee is not considering a decision which is for or against clean air. Instead the issue is to decide what is most logical in respect to the energy crisis.

Secondly, we believe that gas shortages will increase improper fueling of catalyst equipped cars. Several factors could lead to this situation. There will be very limited demand for unleaded gasoline for some time because of the relatively small population of cars needing this fuel. By the fall of 1975, for example, fewer than 10 percent of all cars on the road will require unleaded gasoline. This low level of demand would create supply and distribution problems even in the best of times. Supplying outlying stations with unleaded gasoline, when the demand is low and general shortages prevail, would seem to pose more problems. In times of shortages and allocation of fuel, service stations and wholesale delivery facilities might be more lax in maintaining sterile unleaded gasoline which requires special and dedicated facilities in the various handling and delivery stages.

Possibly of greatest concern are those problems arising out of unleaded fuel shortages. The overall short supply of gasoline could lead to the indiscriminate use of leaded and unleaded fuel. For example, if a station runs out of unleaded gasoline, there may be more tendency to "force feed" catalyst cars with leaded gasoline. If a motorist with a catalyst equipped car ran low on fuel or out of gas altogether, he probably would be happy to get any kind of gas he could—leaded or unleaded—rather than be stranded.

If the law remains unchanged, unleaded fuel will be a necessity for 1975 models with the attendent problems I have mentioned. This could be a logical conclusion of Congress only if it is determined that the total effect upon the energy issue is thus optimized by improved fuel economy.

There has been a great deal of confusion about the effect the 1975 standards will have on fuel economy particularly when catalysts are used. Attachment A is a chart we previously submitted to the Senate Public Works Committee which shows an 8 percent difference in gasoline mileage between cars with and without catalysts while both are designed to meet present 1975 standards. The 1975 fuel economy with catalysts, however, is only 3 percent better than our 1974 models. We understand from testimony and data from oil companies that unleaded gasoline reduces the yield per barrel of crude oil. If so, we would have to conclude that the effects on our petroleum supplies from carrying over 1974 standards and meeting 1975 standards with catalysts would be equivalent.

Another point I want to emphasize is that savings in fuel economy will result if there is a period of stability in the emission requirements we have to meet—that is, if requirements are carried over for two or more years. Although this is difficult to quantify, we are confident that our engineers could do a much more effective job of improving fuel economy if they could work with carryover standards and not have to reengineer and recertify for emissions year after year. For example, when emission standards for 49 states other than California remained the same for the 1973 and 1974 model years, Ford, on the average, improved the fuel economy of its vehicles by 3 percent. If 1974 standards are retained through the 1977 model year, I think we can expect further gains in fuel economy for those years.

In Attachment B, we indicate the effect of fuel economy on Ford cars occurring as a result of imposing two different sets of emission standards beginning with the 1975 model year. Carrying the 1974 standards over for two years and adopting the California interim standards in 1977 (as we recommended to the Senate Public Works Committee) will avoid the premature use of catalysts and actually results in a net fuel savings of 5 percent by 1977. The solid line for 1975 interim standards does not reflect the petroleum refining loss for unleaded fuel if that becomes a requirement for 1975 because of catalyst equipped cars. Attachment C shows the relationship of fuel economy on Ford cars between 1974 carryover and 1975 interim standards carried through 1977.

Let me turn to another point. Last week EPA recommended to Congress certain NO_x standards up through the 1990's, and I think this Committee should review that proposal. The carryover of 1974 emission levels for three years will have advantages in improving fuel economy because the NO_x standards will remain at 3.1 gpm rather than being reduced to 2 grams per mile for the 1976 and 1977 model years. Even though EPA has said that meeting a 2 gpm standard is technically achievable and we do not disagree, our data also clearly shows that meeting tightened NO_x standards by any available technique known to us dramatically depreciates gasoline mileage.

For this reason, we think the present NO_x standards should be retained through the 1977 model year. If this Committee supports that position, I would also recommend that at the same time a NO_x standard of 2 grams per mile be established for 1978 and beyond. As you know, Ford is vitally interested in developing alternate engine concepts which could ultimately eliminate the need for catalysts. Those engines are not feasible if the statutory NO_x standard will ultimately be below 2 grams per mile.

Let me explain. The EPA proposal would establish NO_x controls at 2 grams per mile but only up through 1981 when they would be reduced to 1 gram per mile and then later be reduced to .4 gpm.

Ford Motor Company already has told this Committee that if all our developmental goals were achieved, the best we could do would be to convert one engine line to an alternate engine in 1977. However, we would not want to do even that if we could not anticipate converting the remainder of our thirteen engine lines to this new engine concept on a year-by-year basis. As we have clearly stated, the most promising alternate engines from both emissions control and fuel economy standpoints are those that appear capable of meeting a 2 gpm NO_x standard.

If the EPA proposal is followed, we could not proceed. If did, we would be part way through our conversion of faciliteis when we would be forced to stop conversion and probably abandon the new engine because it does not have the potential to meet a 1 gram standard in 1982.

We must have some assurance that a 2 gpm NO_x standard would be in place for a reasonable time in the future in order to pursue the alternate engine approach we have previously discussed with this Committee. Lacking that assurance we have no recourse but to seek out other alternatives.

To develop realistic developmental goals for our alternate engine research, we need Congressional guidance on future No_x requirements by the end of this year.

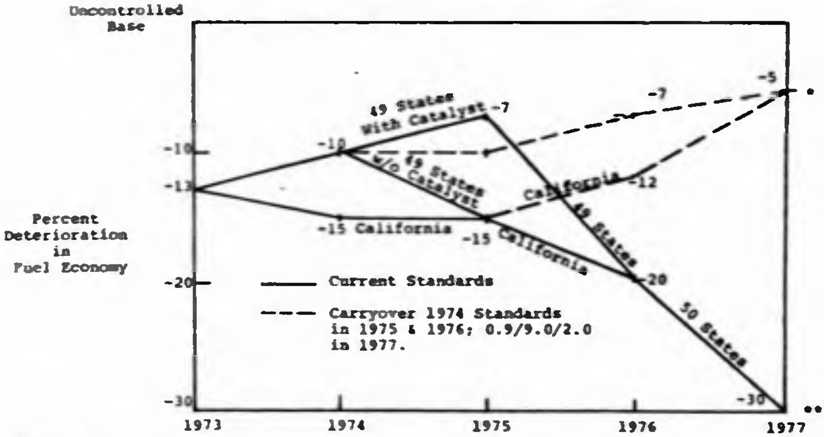
Early Congressional direction is also required for the next few model years on all three vehicle emission standards. For example, we should know before the end of this year what changes will become law with respect to all standards for 1976. We start building 1976 precertification vehicles next spring and need prototype parts now. We must make firm facilities commitiments to our suppliers this month for emission control components for 1976 models. For these reasons, we urgently need immediate Congressional direction. A delay until next year, as recommended to you by EPA yesterday, totally ignores the lead time requirements of our business.

Let me summarize Ford Motor Company's position. We strongly urge that you consider carryover of the 1974 standards—primarily to avoid the use of unleaded fuel during the gasoline shortage—but also to avoid the risks associated with massive application of new catalyst technology.

We further request that you provide immediate direction for the NO_x levels you plan to establish for 1978 and beyond so that we can intelligently plan our alternate engine research. Finally, we ask for Congressional direction on these vehicle emission standards this month so we can meet the urgent needs of preparing for production of 1976 models. Perhaps the best way to do this would be to amend the emergency energy bill now pending before the House Interstate and Foreign Commerce Committee. A bill which has already passed the U.S. Senate.

Thank you for this opportunity to present our views on these vital matters. We have tried to make it clear that we are convinced it woud be counter productive to alleviation of the energy shortage to do anything but carry over 1974 emission standards and continue the use of leaded fuel for the next few years.

EFFECT OF EMISSIONS CONTROLS
ON AVERAGE FORD MOTOR COMPANY CAR FUEL ECONOMY

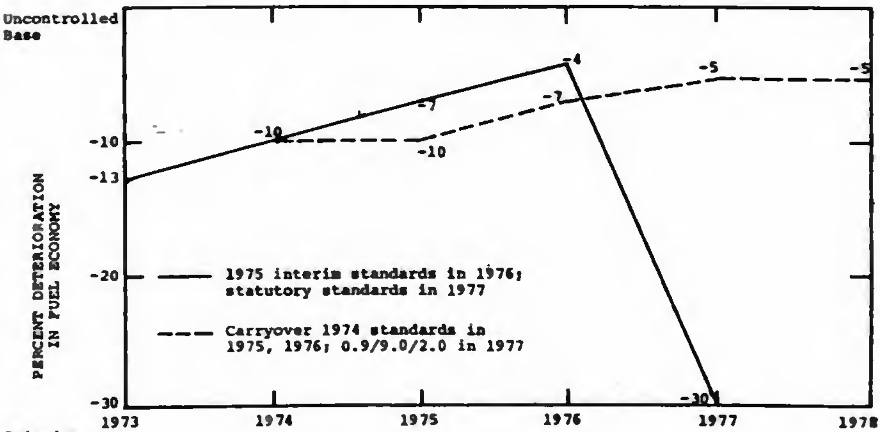


Emissions Standards Gms/Mile	50S	49S	Calif.	49S	Calif.	50S	50S**	Proposed*
HC	3.4a/	3.4	3.2	1.5	0.9	0.41	0.41	0.9
CO	39.0	39.0	39.0	15.0	9.0	3.4	3.4	9.0
NO_x	3.1	3.1	2.0	3.1	2.0	2.0	0.4	2.0

a/ 3.2 Gm/mile in California.

ATTACHMENT A

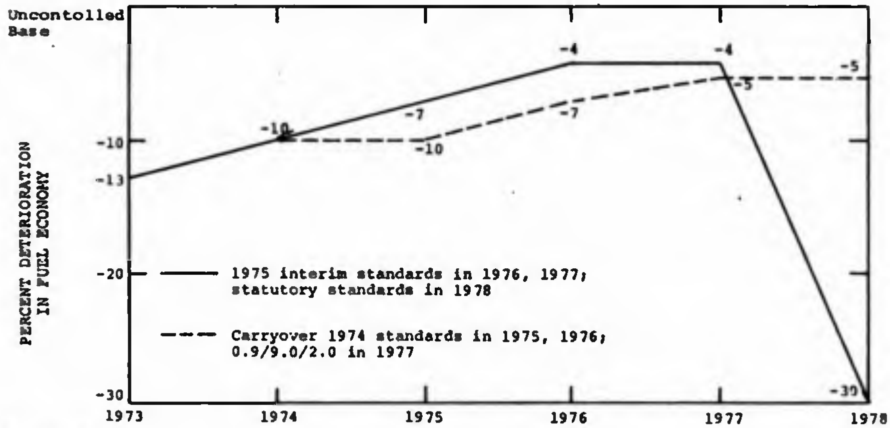
EFFECT OF EMISSIONS CONTROLS
ON AVERAGE FORD MOTOR COMPANY CAR FUEL ECONOMY



Emissions Standards gm/mile						
HC	3.4	3.4	1.5	1.5	0.41	0.9
CO	39.0	39.0	15.0	15.0	3.4	9.0
NO_x	3.1	3.1	3.1	3.1	0.4	2.0
						Proposed

ATTACHMENT B

EFFECT ON EMISSIONS CONTROLS
ON AVERAGE FORD MOTOR COMPANY CAR FUEL ECONOMY



Emissions Standerds gm/mile							
HC	3.4	3.4	1.5	1.5	1.5	0.41	0.9
CO	39.0	39.0	15.0	15.0	15.0	3.4	9.0
NO_x	3.1	3.1	3.1	3.1	3.1	0.4	2.0

Proposed

ATTACHMENT C

Mr. ROGERS. Thank you very much, Mr. Misch.

Mr. Terry from Chrysler, if you could let us have your statement, please.

STATEMENT OF SYDNEY L. TERRY

Mr. TERRY. Yes, sir.

My name is Sydney L. Terry, vice president of safety and environmental relations from Chrysler. With me today are Mr. Victor Tomlinson of our legal staff and Mr. Charles Heinen, director of vehicle emissions.

In the brief time we have available today we would like to make just a few points with regard to the issues of automotive emissions, fuel economy, and automobile design.

First, let me make it clear that Chrysler Corp. is fully prepared to build and sell catalyst-equipped cars in 1975 which will meet the emissions standards both for California and federally for that model year. We know that our Chrysler developed catalysts are fully competitive, and we are now running certification tests of our 1975 systems. If it is the will of Congress that the American people should pay the price in dollars and in natural resources for these systems with their attendant benefits and their attendant liabilities we are ready to accept that judgment. But we continue to believe that a carryover of the 1974 standards, which already removes 70 percent of automotive emissions, is the proper way to go.

We continue to believe that the recent Senate Public Works Committee's decision to commit 1975 car buyers to the purchase of catalyst-equipped cars is a serious mistake for the Nation—not for Chrysler, but for the country. After all, the recent debate and the claims and counterclaims about the merits of catalytic converters, several unassailable facts still remain.

Fact one—a catalyst-equipped car will impose on the individual car buyer a penalty of approximately $150 in original cost, and even more in operating and maintenance costs.

Fact two—the lead-free fuel required for catalysts will, by the end of 1975, cause a loss of crude oil at the Nation's refineries of at least 1 million gallons a day.

Fact three—if the concern over the acceleration of sulfate emissions from catalysts turns out to be valid, the removal of sulfur from gasoline will cause an additional drain of up to 4 percent on crude oil supplies.

Fact four—only 45 percent of the Nation's gas stations will have lead-free fuel. Under normal circumstances this might be acceptable. However, during the current severe gasoline shortage which may persist for some time, it is clearly unacceptable. The motorist who has difficulty finding gasoline of any kind will be seriously tempted to force feed regular leaded gasoline into the fuel tank of his catalyst-equipped car. This action will poison the catalyst and make it ineffective, with the result that the vehicle could produce more emissions than a non-catalyst car. We fully expect that when careful inspections are finally made in a few years, the incidence of poisoned and burned-out catalysts will be found to be unacceptably high. And that is why we are very reluctant to put catalysts on the high percentage of our cars next year.

Fact five—the so-called improved fuel economy which has been claimed for catalyst equipped cars is largely illusory. The claim for a sales-weighted average improvement is little more than a statement that small cars use less gas than big cars, and a larger percentage of small cars will be produced in 1975. The average gain per vehicle is actually on the order of 3 percent according to our tests, doing the best job we can to improve fuel economy with the catalysts. This is easily offset by the crude oil loss of 5 to 7 percent in refining and burning of lead-free gasoline.

Fact six—the multimillion-dollar national commitment to catalyst converters, to unleaded gasoline supplies and delivery systems, and to a necessary system of inspection stations, will be nearly impossible to reverse. And it will surely delay the introduction of superior alternate technology.

Fact seven—the final result of all these extreme penalties will be a difference in air quality between 1974 and 1975 standards and will be so small, according to Dr. Greenfield of the EPA, as to be undetectable in the first year.

The list could go on, but we believe these few facts should be reemphasized as this committee considers this critical issue. We continue to believe strongly that the 1974 emissions standards should be carried over until the National Academy of Sciences can recommend what actually needs to be done to protect health and to conserve resources. If we do not wait, this half-million-dollar study will be wasted. A carryover of the present standards would also avoid all the serious risks I have just enumerated.

Now, a few remarks as to the specifics of H.R. 10118. As a general principle, we believe that assigning responsibility to the EPA to set standards vitally affecting motor vehicle performance in many ways would create serious jurisdictional problems. If standards designed to improve fuel economy are in fact required, they might better be in the Department of Transportation where standards for automobile safety are already established. There are inevitable tradeoffs between safety standards and fuel economy standards which must be carefully analyzed for overall effect and desirability before such standards are mandated.

Beyond that general principle, let me comment just briefly on each of the subsections of the bill.

A. On fuel economy labeling. If an acceptably accurate method of determining fuel economy can be established, one that is representative of ordinary, everyday driving, we strongly support the principle of making such data available to the purchaser of a new car.

B. On establishing fuel economy standards. We believe that the imposition of fuel economy standards would inhibit the utility of many kinds of cars in many adverse ways, many impossible to predict even at this point in time. We have testified on this before the Senate Committee of Commerce in some detail and would be pleased to submit our statement on that for the record.

Mr. ROGERS. Without objection it will be made a part of the record.

Mr. TERRY. As to (C), (D), and (E), on requirements which would encourage greater fuel economy. We believe that the natural pressures of the marketplace, which are being felt very strongly in Detroit, as you are reading every day in the papers, will bring improved fuel economy as fast as any requirement written into law, and bring it in ways that will give us cars that do a better job of serving the transportation needs of this country. As just one example, in the 1974 calendar year, in response to market demand, we will be ready to build over half of our total production as small cars. We could not have converted our plants any faster.

(F) On limitations on emission controls which impede fuel economy. We support this provision, pointing out that the emission controls on today's cars cause a fuel economy loss, that the lead-free fuel requirement for 1975 does waste additional crude oil, and that emission standards on the books for 1976 and 1977 will cause a serious additional fuel economy penalty on all automobiles.

This ends our testimony. We will be happy to answer any questions you might have.

Thank you very much.

[Mr. Terry's statement before the Senate Commerce Committee, referred to, follows:]

STATEMENT BY SYDNEY L. TERRY, VICE PRESIDENT, ENVIRONMENTAL AND SAFETY RELATIONS, CHRYSLER CORP., BEFORE THE SENATE COMMITTEE ON COMMERCE, WASHINGTON, D.C., JUNE 21, 1973

My name is Sydney L. Terry. I am Vice President, Environmental and Safety Relations, for Chrysler Corporation. With me today are Mr. George J. Huebner, Director of Research, and Mr. V. C. Tomlinson of our Legal Staff.

We are pleased to have this opportunity to express our views on the Automotive Transport Research and Development Act of 1973 and the Motor Vehicle

Fuel Economy Act. Before commenting on the specific provisions of these bills, I would like to discuss Chrysler Corporation's position on the environment and the energy crisis—the two national issues which have led to these hearings.

Let me begin with the question of the environment. Chrysler Corporation is committed to eliminating the automobile's share of the country's air pollution problem. Our record over the years in developing effective controls is well known. Automotive emissions have been reduced an average of 70 percent from uncontrolled levels. During the 1950s and 1960s, we also explored a number of substitutes for the internal combustion engine. But for this period it was our best engineering judgment that the most reliable and economical power plant we could possibly offer our customers was the internal combustion engine.

That engine has now become the object of attack because of its alleged inefficiency and supposedly high fuel consumption. In considering that criticism there are three facts I would like to call to your attention. First, during the 1960s, there was a growing public demand for power equipment, air conditioning, automatic transmissions, and other options which tended to increase fuel consumption. Our customers also sought larger cars and higher horsepower engines for the longer trips they were taking on the country's freeways. And this, too, has had an adverse effect on fuel economy. Nevertheless our engineers have in part offset this effect primarily through stringent weight control programs. And controlling the weight of vehicles continues to be one of our most important engineering considerations.

Second, there was a steady increase in vehicle weight largely as a result of government mandated safety and emissions equipment. As a direct result, between 1963 and 1973 we had to add 152 pounds to a compact four-door Valiant. If you take account of the other changes we have had to make to maintain performance and durability because of the government requirements, the total safety and emissions related weight additions comes to 261 pounds. Next year's federally mandated bumpers will add an additional 100 pounds. And I might point out that the weight increases on intermediate and standard size cars are even greater. Weight, of course, has an adverse effect on fuel economy. One of our primary engineering objectives has been to offset the effect of these government safety regulations by reducing the weight of a vehicle's components wherever we can.

Third, the passage of the Clean Air Act of 1970 was a setback for this steady progress to control emissions and preserve good fuel economy. That law, as you know, mandated 93 to 97 percent reductions in automotive emissions from uncontrolled levels. And it allowed us less than five years to meet these extremely stringent standards. As the Administrator of the Environmental Protection Agency indicated, in the time available to the industry the only power plant with any hope of meeting the standards that could be produced in volume was the internal combustion engine equipped with catalysts or some other add-on device to treat the exhaust.

The National Academy of Sciences, the Federation of American Scientists, the Office of Science and Technology, and even the Environmental Protection Agency, among others, have all recently concluded that the catalytic control system is a less than desirable control system. We agree. The catalytic system is expensive. Importing the quantities of platinum and palladium required for catalysts will make a major industry dependent on foreign nations. Catalysts will require expensive unleaded fuel. As you know, it requires more crude oil at the refinery to produce a gallon of lead free fuel. A report by the Office of Emergency Preparedness on the energy crisis issued last year said that the use of dual catalysts to meet the 1976 standards will be counter-productive because of a fuel penalty of 15 to 20 percent.

As these facts have become clear, there has been a growing recognition that government programs, including the Clean Air Act itself, may actually have set back the development of alternate power plants and more efficient engines. The overly stringent numbers Congress set have eliminated some engines from present serious consideration. The turbine engine, for example, cannot presently meet the 1976 oxides of nitrogen standard of 0.4 grams per mile.

As you know, Chrysler's president, John Riccardo discussed many of these points on May 31 before the Senate Air and Water Pollution Subcommittee. Since much of what Mr. Riccardo said bears directly on today's subject, I would like to submit a copy of his statement for the record.

Chrysler Corporation is certainly not permanently committed to the piston engine's continued and exclusive usage. In this regard, Mr. Riccardo's testimony provides a brief evaluation of the various other power plants that have been proposed—the diesel, the rotary, the stratified charge, and so on.

We at Chrysler have always believed that the most promising new approach to automotive power is the gas turbine engine. We tested a fleet in actual customer use in the 1960s. We have continued to develop this engine. We recently signed a contract with the Environmental Protection Agency for further turbine research. Basically, the turbine is an efficient engine. It can operate on many different types of fuel. It can easily pass the 1975 carbon monoxide and hydrocarbon emission standards. But it does not meet the 1976 oxides of nitrogen standard of .4 grams per mile.

Based on work with our sixth generation turbine engine, we believe the turbine could meet an oxides of nitrogen standard of something less than two grams per mile—perhaps as little as 1.5 grams per mile. But as long as the standard for NO_x remains at 0.4 grams per mile, major development programs to solve some of the remaining problems and any plans to put gas turbines in passenger cars must be indefinitely delayed.

The greatest impetus to the development of new power plants that are more efficient and that burn less fuel would clearly be a more stable outlook for future emission standards—that is necessary but reasonable standards and a more realistic timetable for implementation. In this regard, we hope Congress will act quickly on the recommendations of the Environmental Protection Agency and bring the oxides of nitrogen standard into line with the known medical and technological facts. A more reasonable oxides of nitrogen standard would resolve some of the present uncertainty as to the suitability of the Honda and diesel engines, and would make the turbine a viable alternative to the present piston engine.

We do not believe that the Automotive Transport Research and Develpment Act is needed to stimulate development of a new engine. Experience of government and industry prove we cannot invent on a timetable, or solve a problem simply by throwing money at it. More important, as the Environmental Protection Agency told this committee, ". . . the competitive forces in . . . (the auto) industry . . . are sufficiently great as to provide a high degree of confidence that—given the proper circumstances—industry can be expected to do the job that needs to be done."

In this case, proper circumstances are realistic standards and adequate lead time needed to develop a new engine, complete the testing, secure the tooling and facilities, and convert the entire industry to production of a new power plant. The Department of Transportation and others estimate that it would take 10 to 12 years—no three years.

This is not to say that government should not be supporting research programs. It should. But we feel government funds are best invested in basic research.

In its own programs, EPA has supported research into power plants that have long-range potential—the turbine, the Rankine Cycle, various hybrid engines, and so on. But quite properly, it has not tried to dictate the design of a new motor vehicle engine to meet the 1975–76 standards.

We believe EPA is following a sound approach to the problem. And we do not think that its efforts should be replaced or superseded by a new government agency.

Applied research is best left to the private sector. The consumer will tell us, by the choices he makes in a free market, what he wants and what he doesn't want. And I cannot think of a more powerful incentive to encourage the automobile manufacturers to improve their present engines, or develop new power plants that are low in emissions, high on fuel economy, and reasonable in cost. As EPA said, "There is no special genius that derives from federal sponsorship of development efforts." And as you may recall, EPA warned of the risks of substituting federal decision-making for the forces of the marketplace. And it recommended against the Automotive Transport and Development Act. We agree with EPA.

And for the same reason that we and EPA do not support this Act, we at Chrysler do not support the Motor Vehicle Fuel Economy Act.

This bill requires that the aggregate or total amount of fuel consumed by 1979 model vehicles be 25 percent less than fuel consumed by 1973 models, and it would have the Secretary reach that objective by setting fuel economy standards for all kinds and classes of vehicles. This would completely smother the car market. It would have serious adverse consequences that we think its authors did not foresee and do not intend. If the bill is interpreted literally, it would require severe restrictions on the individual motorists as well as the manufacturer.

The fact is that the automobile manufacturers alone cannot achieve the objective of this bill simply by improving the fuel economy of each of their vehicles by 25 percent—even if that were possible in the time the law allows. Remember, the bill as presently written sets a limit on total quantity of fuel consumed by all new cars. What that amount will be depends on a number of factors that are beyond the control of the manufacturers and the Secretary.

First, compact vehicles generally consume less fuel per mile than standard size cars. Thus the total amount of fuel consumed depends not just on the number of cars sold, but also on the kind of cars. Obviously, if the percentage of compact vehicles increases, the total fuel economy will improve and vice versa. If we hope to control the total amount of fuel consumed, then we will have to control both the number of vehicles sold, and the kind of cars that are sold. We do not think the authors intended that the Department of Transportation should be given total control of the automobile market by rationing the kind of vehicles that public can buy, or establishing a quota for the size and weight of vehicles that the manufacturers can produce.

Second, the amount of fuel consumed depends on the number of miles that people drive their cars. We don't think the authors intended the Department of Transportation to restrict the personal freedom of people by limiting how many miles they can drive each year. And some such restrictions would be necessary if we were to effectively reduce the amount of fuel used by 25 percent.

Third, the way people drive determines fuel economy. For example, the practice of consistently fast starts in city traffic can increase consumption by as much as 18 percent. Or consider the freeway driver who doesn't hold a steady speed of 60 miles an hour, but lets the speed drift up and down within a range of five miles. He can suffer a fuel penalty of as much as nine percent. Some tests at our Proving Grounds show that under some conditions a smaller engine will actually burn more gas per mile than a larger engine that is not being pushed to its capacity. Contrary to popular opinion engine size alone is not the governing factor.

Fourth, the manufacturers cannot control the way drivers maintain their vehicles. If the engine timing is out of adjustment, or if the tires are underinflated, there will be a fuel economy loss.

Yet all of these factors beyond the manufacturer's control—the number of cars people buy, the mix of new cars they buy, the optional accessories they choose, the total mileage they drive those cars, and the way the drive and maintain them—must all be carefully controlled if we are to reduce total automotive fuel consumption.

This is not to say that the public cannot expect better fuel economy. It can. Our customers are demanding it. And to the best of our ability, we will give them what they demand. Right now, they want smaller, more economical vehicles. This trend started in the 1960s, is growing stronger in the 1970s. For example, back in the 1964 model year, small cars accounted for 25 percent of the market. By the end of the 1972 model year, that share had increased to more than 38 percent. And through May of the 1973 model year, the small car share has been over 40 percent. With the expected increase in gasoline prices in a free and open market, the trend to smaller and more economical cars is sure to continue.

The fact is that the public's choice in motor vehicles is determined by what it costs to own and operate a car. In the 1960s the demand for big engines and so-called performance cars died almost as quickly as it started when rising insurance rates made these cars uneconomical.

The public is already telling us that they want better fuel economy. There is no need for the government to echo what we are hearing in the marketplace.

The fact is that in any year, a year's production of new cars consume less than one percent of the country's total energy. So even if fuel consumption of all new cars were cut 25 percent in 1978, the maximum possible savings in that year would be only one quarter of one percent of the total energy the country will use in that year. And even by 1985, when most cars would meet these standards, the savings as far as total energy is concerned would still be less than two percent of the nation's usage. We think these numbers show that fuel economy standards for new cars is not an effective way of reducing the country's energy usage.

However, there are two areas where government action may be desirable and even necessary. First, rather than trying to control demand for fuel through artificial means, we believe government should encourage development of new sources of supply.

In the view of economists and many others, a major reason for the present energy crunch is that the country has not been drilling the wells and investing in refineries and transport systems at a fast enough rate to keep pace with its growing demands because of criticism and opposition of some environmental groups. In addition, controls on the price of natural gas at the well head have created an artificial demand for gas, held down the price of petroleum, and cut incentive for risk capital. Before trying to solve our problems by imposing fuel economy standards on the auto industry, we believe Congress should carefully evaluate some other courses of action, and determine the ways to increase our present energy supply.

Second, before imposing new restrictions on the industry, government should first review the controls it has already placed on us. As I pointed out, many safety standards add otherwise unnecessary weight to a vehicle and adversely affect emissions and fuel economy. The emissions standards set by the Clean Air Act will lead to higher fuel penalties. And so it goes. We are being whipsawed by requirements established by the Department of Transportation, the Environmental Protection Agency, and the Congress. The fuel economy standards, added to other requirements already on the books could create unsolvable engineering problems.

We urge you to examine these regulations and resolve the present conflicts in the laws that affect our business. Nothing Congress could do would be more important or more beneficial to the public.

We have some serious reservations about the Motor Vehicle Fuel Economy Act that I would like to mention briefly.

First, the bill does not deal with the basic facts of automotive engineering. An engine is not designed just for fuel economy, emissions, or any other single criterion. We must also take account of many factors—emissions, driveability, performance, noise, reliability, economy, and so on.

Whatever we do in one area often involves trade-offs in the other areas. It may be that the requirements of the fuel standards and mission standards are completely irreconcilable in the time the law allows.

Second, the bill directs the Secretary of Transportation to consider the economic and environmental effects of the fuel economy standards. But even if he finds that the fuel economy standard is in direct conflict and irreconcilable with emission standards, he is powerless under this bill to modify that standard. One of the serious problems with the Clean Air Act is that once the standards were set, the Administrator had no authority to change them even though new evidence showed they should be changed. That experience shows we should not follow the same course with fuel economy standards. And I might add that the experience with the Clean Air Act shows that before we set any standards, we should take the time to carefully evaluate the need, and identify the costs and benefits as accurately as possible. We do not serve the public interest by going ahead with laws that are more restrictive than needed—or which may not even be needed at all.

Third, the test procedures established by the bill require that we test "each model of motor vehicle equipped with each and combinations of each type of optional accessory" that could effect fuel economy. That includes engines, tires, power equipment, transmissions, and so on. At the present time, Chrysler Corporation could build some one and one-half million different vehicles just by changing the mix of the various options. If we consider only those options that might affect fuel performance, we are probably talking about 100,000 or more different vehicles. That means 100,000 tests. We believe that the test procedure is impractical.

Fourth, the bill states that the manufacturer must pay a fee equal to 15 percent of the retail price of the car if the car meets the fuel economy standard. The effect is to penalize a company producing a car that complies with the law. We do not believe that this is a fair or practical approach to the problem.

You may be sure that we at Chrysler are looking for the same results which both bills seek. We want to give our customers a clean and reliable engine with good mileage that is economical to produce. We are constantly working toward that end.

This engine may turn out to be some form of the present piston engine. It may be a gas turbine. It may be an engine we know very little of today. There may well be several kinds of engines being mass-produced for different applications in the cars and trucks of tomorrow. We are exploring all the possibilities. And we will work out the answer in the give and take of a free market. In view of present programs in the public and private sectors, we do not believe either bill is necessary or in the public interest.

Mr. ROGERS. Thank you very much, Mr. Terry.
Now. Mr. Edward N. Cole. president of General Motors.

STATEMENT OF EDWARD N. COLE

Mr. COLE. Mr. Chairman, members of the Public Health and Environment Subcommittee, I am Edward N. Cole, president of General Motors.

We appreciate the opportunity to appear at these important hearings to discuss the need for changes in the motor vehicle emission standards and deadlines established by the Clean Air Amendments of 1970. In the time allotted we will address ourselves in our statement principally to the emission standards, and we are prepared to respond to other matters during your question session.

As you know, Mr. Chairman, a number of issues under consideration here today were discussed in our testimony before your subcommittee on September 13. I understand you and your staff also are familiar with the testimony we presented to the Senate Public Works Committee on November 5. In our prepared statement, therefore, we shall discuss only those issues which need to be emphasized.

Foremost among these is the gain in fuel economy we expect to realize as a result of our decision to use catalytic converters on most if not all of our 1975 cars and what this fuel economy gain may mean in terms of reduced gasoline consumption. Another major consideration, from our standpoint, is the need for stability in the standards which must be met over the next few critical years pending the resolution of questions pertaining to emission standards beyond the 1975 model year.

FUEL ECONOMY

Since our previous testimony before this subcommittee on September 13, we have accumulated considerably more fuel economy data. We are encouraged that our current data support our earlier findings that there would be a fuel economy gain on GM's 1975 products. Those data, sales weighted, indicate the gain will be approximately 13 percent over 1974 GM models on combined GM city and GM highway driving schedules.

CRUDE OIL REQUIREMENT

As we have said before, successful use of catalytic converters depends on the availability of unleaded fuel. We do not believe that additional crude oil will be required to supply this unleaded fuel for 1975 vehicles equipped with catalytic converters. By the end of the 1975 model year, only about 10 percent of the vehicles on the road would require unleaded fuel, even if all 1975 models are equipped with catalytic converters. Hence, there is no need for an immediate massive conversion of refinery equipment in order to make unleaded gasoline available for 1975 models. The production of unleaded fuel would, of course, have to be increased year by year as the total number of cars with catalytic converters increases.

While we do not presume to be experts in gasoline production, we understand that, on a nationwide basis, up to 50 percent of gasoline production could be made unleaded at 91 research octane number, and 83 motor octane number, without crude oil utilization penalty. Based on current attrition rates, it would be about 10 years before the cars on the road requiring unleaded gasoline would approach 100 percent. Even so, this is based on the assumption all 1975 and subsequent year cars are equipped with catalytic converters.

It was the understanding that unleaded gasoline at 91 research octane number can be produced with very little or no crude oil penalty which led us, in 1971, to reduce the compression ratio of all GM cars to a point where they would operate satisfactorily on 91 research octane number fuel. We have no plans to increase the compression ratio and thus require octane numbers higher than 91.

In 1970, before our compression ratios were reduced, regular fuel at 93 to 94 research octane number satisfied the octane requirements of 50 to 60 percent of GM cars and premium fuel at 98 to 100 research octane number was required for the remainder of our production.

As a result of the compression ratio reductions since the 1971 model year, the need for premium fuel, primarily for pre-1971 cars still on the road, will be about 22 percent of the total by the end of the 1974 model year. It will be about 19 percent by the end of the 1975 model year, as later model cars make up an increased percentage of the car population.

The unleaded base stock for premium, and that is 98 to 100 research octane number fuel, ranges generally from 93 to 94 research octane number. Thus, as the need for premium fuel decreases, an increasing percentage of this premium base stock can be diverted to producing unleaded fuel at 91 research octane number.

1975 INTERIM STANDARDS

General Motors has made an all-out effort to meet the 1975 interim standards as promulgated by EPA. After considerable research into various alternative methods of emission control, we determined that catalytic converters offered the greatest potential for meeting future emission requirements in the time available; and recent further research and testing has borne this out. As a result, we have concentrated on catalytic converters, along with improvements in carburetion and ignition, in our 1975 model development.

We are confident we can meet the 1975 interim standards, using catalytic converters on most, if not all, of our 1975 products. We believe those standards will provide the basis for control systems that will insure continued decline in the contribution of motor vehicles to urban air pollution. At the same time, the use of the GM catalytic converter system will make it possible to provide car owners with improved fuel economy and driveability, as well as reduced maintenance costs.

POST-1975 STANDARDS

As we have previously informed you, we do not know how to meet all the requirements of the 1976 interim standards, and the 1977 statutory standards under existing certification regulations. Furthermore, as we attempt to achieve these lower levels of emissions, the expected fuel economy gains for 1975, regretfully, decrease significantly.

On previous occasions we have urged the continuation of emission standard levels no more stringent than the 1975 interim California standards for the 1976 and 1977 model years. You may recognize, however, that the California interim standards would result in a fuel economy penalty, compared with the 1975 interim levels for the rest of the country, and the 1975 interim Federal standards, as you know, are 1.5 grams per mile of hydrocarbon, 15 grams per mile carbon monoxide, and 3.1 grams per mile of oxides and nitrogen.

We strongly urge consideration of the fuel economy factor in establishing emission levels as low as those presently required in 1975 for California.

If it is determined that more stringent levels are needed for California's ambient air quality, this can be achieved, but with a fuel economy penalty.

We believe continuing the 1975 standards for an additional 2 years at the 1975 interim Federal level represents the optimum combination of emission control and fuel economy with current technology. In view of the expected improvement in fuel economy resulting from engine modifications permitted by the use of the catalytic converters, billions of gallons of gasoline would be saved during the 3-year period from just GM cars alone.

We want to continue to work with the EPA and Congress to achieve the goal we are all seeking: Elimination of the automobile as an element in the Nation's concern over air pollution at the earliest possible time.

We are pleased at this time to respond to any questions you may have.

Mr. ROGERS. Thank you very much, gentlemen, for those statements. and Mr. Satterfield, would you like to begin questioning?

Mr. SATTERFIELD. Thank you, Mr. Chairman.

Mr. Cole, I believe you state that the gain in your vehicles with use of a catalytic converter will be 13 percent over 1974 GM models?

Mr. COLE. That is correct. That is on a sales-weighted basis.

Mr. SATTERFIELD. What do you mean by a sales-weighted basis?

Mr. COLE. A sales-weighted basis means that it is likely that some of our smaller cars will probably have a greater demand than they have currently, and we have weighted that into our forecast. The change in sales weighting over the sales weighting that we had in 1974, represents about 3 percent of that gain out of the total of 13.

Mr. SATTERFIELD. Do you have the figures here today or will you furnish them to this committee showing how you arrive at that 13-percent figure?

Mr. COLE. Yes, sir. We have them here today and we will be glad to furnish the committee this information.

Mr. SATTERFIELD. Mr. Chairman, I move that they be accepted into the record.

Mr. ROGERS. Without objection, it will be made a part of the record.

[The following information was received for the record:]

SUPPORT DATA FOR 13% GM FUEL ECONOMY IMPROVEMENT ON 1975 MODELS

Currently, passenger car driving in the United States consumes about 29% of total petroleum usage. Although GM's 1975 emission control system—which includes the use of a catalytic converter—was designed and developed primarily as a system to control exhaust emissions, it also permits an improvement in fuel economy. Based on the question of how much gasoline GM's 1975 model passenger cars will consume, fuel economy data taken from experimental cars made up of a projected 1975 model mix compared with data from 1974 model vehicles, indicates that:

In city driving, fuel economy is approximately 15% better.

In highway driving, fuel economy is more than 10% better.

While the data which is shown in Figure 1 is from engineering and development tests to date. GM feels they fairly represent the magnitude of the fuel economy improvement which can be expected from our 1975 model passenger cars and that they support previous GM statements that this gain will be approximately 13%.

SUMMARY OF DATA USED IN FUEL ECONOMY CALCULATIONS AND COMPARISONS

[Data on 1975 models taken from experimental cars to permit estimation of fuel economy]

Engine family	Percent of production volume		City miles per gallon		Highway miles per gallon	
	1974	1975	1974	1975, with converter	1974	1975, with converter
Chevrolet 101	7.50	11.57	23.7	21.8	25.3	24.7
Chevrolet 102	3.35	2.15	14.6	16.7	18.0	17.7
Chevrolet 104	43.65	37.10	10.7	12.0	12.4	13.5
Pontiac 201	8.75	8.58	12.5	13.2	14.5	15.7
Pontiac 202	5.01	5.42	11.4	12.1	13.7	15.0
Oldsmobile 301	9.18	10.46	11.6	14.5	14.6	15.6
Oldsmobile 302	5.80	3.76	10.0	12.2	12.8	13.6
Buick 401	6.65	8.82	11.6	13.7	14.4	15.2
Buick 402	5.99	5.98	9.7	12.1	11.6	14.8
Cadillac 501	4.12	6.14	10.7	11.4	12.3	12.8
Sales weighted average, miles per gallon: Using applicable year mix from pt. I information			11.5	13.2	13.6	15.4
1974 to 1975 fuel economy improvement (percent)				15		10.6

Mr. SATTERFIELD. Now, I notice you made a statement here—let me see if I can find it. Yes, on page 3, at the bottom you said the unleaded base stock for premium fuel ranges generally from 93 to 94 RON.

Are you talking about the pool, now?

Mr. COLE. I am talking about the base fuel, unleaded for premium fuel, prior to leading.

The premium fuel runs in the range, with lead in it, about 98 to 100 RON, and 3 grams of tetraethyl lead adds approximately seven octane numbers to the research octane numbers of the fuel.

Mr. SATTERFIELD. Is it not a fact that the pool, general pool is about 88½ octane?

Mr. COLE. It is about 89 today but when we made our determination and studied the pool, it was 90.6, and some of this has happened because of the reduction in premium fuel requirement because there is not the need for the 93, 94 today that we had at the time that we made our determination back in 1970. So there has been some depreciation in the octane level of the pool currently, compared to what it was in 1970.

Mr. SATTERFIELD. You seem to indicate that there would not be any penalty to go to nonleaded 91 octane gasoline.

Did you mean to say that?

Mr. COLE. I did, sir, and this is based on a study that we had made by Arthur D. Little. We did not feel that we were competent in the gasoline production field, but we felt that Arthur D. Little did have this capability, and we will be glad to submit to this committee their findings indicating that over 50 percent of the fuel could be produced as unleaded at 91 RON without an impact or a penalty on crude.

Mr. SATTERFIELD. Well, I would be interested in knowing your views of how you go from 88½ to 91 with no lead?

Mr. COLE. Well, you are going to depreciate some of the—for example, you are going to depreciate some of the premium fuel requirement, and those octane numbers can go to raise the small percentage of unleaded fuel that you need, and——

Mr. SATTERFIELD. Well, if your pool is 88.5 and you have got to go to 91, you have got to add something, have you not?

Mr. COLE. No.

Mr. SATTERFIELD. Then you are going to suffer a fuel loss.

Mr. COLE. You have already the higher octane numbers available because everything is not pool fuel, and all your——

Mr. SATTERFIELD. I understand that, but when we are talking about 88½, we are talking about the average, are we not?

Mr. COLE. This is right, but some of that average is raised by the adding of 3 grams of tetraethyl lead to raise it up to 93 and 94.

Mr. SATTERFIELD. I understand that, but we are talking about nonleaded gasoline.

Mr. COLE. That is right.

Mr. SATTERFIELD. How are you going to go to nonleaded gasoline without there being a penalty?

Mr. COLE. They are doing it today, sir.

Mr. SATTERFIELD. On the whole pool?

Mr. COLE. No, I did not say the whole pool. We do not expect to use the whole pool. We are talking about using the——

Mr. SATTERFIELD. You are talking about using the top half of the pool.

Mr. COLE. We are talking about 10 percent of the pool, that is what we are talking about, as the maximum need at the end of 1975.

Mr. SATTERFIELD. What are you going to do with the bottom 10 percent?

Mr. COLE. You are going to sweeten it up with tetraethyl lead.

Mr. SATTERFIELD. They either put the lead in there or there will be a penalty.

Mr. COLE. There are cars that can use lead—and 90 percent of the cars on the road can use the leaded fuel—there are cars that cannot. Those cars will require a catalyst—and not all cars necessarily will need a catalytic converter in 1975—cannot use lead. Therefore, we have assumed that at most 10 percent, which would mean that all new cars in 1975, would have a catalyst.

Mr. SATTERFIELD. You also are taking into consideration that there will be lead added into all but the other 10 percent.

Mr. COLE. Not necessarily, not necessarily. For example, there is one well-known petroleum refining industry that is producing 100 octane fuel today as a premium fuel with no lead.

Mr. SATTERFIELD. And I bet they have got a lot of other gasoline they cannot use unless they add lead to it.

Mr. COLE. I do not know about that.

Mr. SATTERFIELD. Does that not figure into the overall picture when we are talking about all the quantity available for the Nation?

Mr. COLE. I believe we have the A. D. Little report, and we would like to submit it as a part of the record.

Mr. SATTERFIELD. I would like to see it.

Mr. COLE. And I think this pretty well explains how they believe that better than 50 percent of the fuel can be made unleaded without a penalty on the crude stocks.

Mr. ROGERS. Without objection, it will be made a part of the record.

[Testimony resumes on p. 256.]

[The A. D. Little report referred to follows:]

OVERVIEW

U.S. REFINING CAPABILITY TO SUPPLY PROPOSED NEW GM MOTOR GASOLINES

Report to

GENERAL MOTORS CORPORATION

December 1973

C-75992

Arthur D. Little, Inc.

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I. SUMMARY AND CONCLUSIONS

A. INTRODUCTION

The technical staffs of General Motors Corporation (GM) have devoted considerable efforts toward developing satisfactory methods to meet the proposed 1975/1976 automobile emissions standards. After extensive laboratory and engineering investigations, GM has concluded that the most reasonable approach for U.S. automobiles to achieve the proposed emissions standards is the use of catalytic afterburner devices. Since lead anti-knock additives which are present in most of today's motor gasolines act as poisons to the catalytic devices, it is necessary to consider the implications of requiring lead-free motor gasolines. The new emissions standards could also require significant changes in present motor gasoline volatility, especially to traverse the 30 second engine warm-up period. In order to meet 1975/76 emissions standards, GM has developed and suggested new specifications for motor gasolines which will satisfy the requirements of catalytic afterburner devices as well as early engine warm-up standards. In mid-1973 GM commissioned Arthur D. Little, Inc. (ADL) to conduct an overview study of the U.S. refining industry to determine its ability to respond to these proposed new revisions in motor gasoline specifications.

The scope of this study was to simplify the overall U.S. refining industry with a computer model "composite" refinery representing the major portion of U.S. motor gasoline supply. This simplified model would study the yield and associated economic implications of producing several grades and production levels of special GM gasolines. Accordingly, our basic ADL refinery simulator model was revised to incorporate the GM specifications. We considered two time periods in this analysis – 1973 and 1980 operations. Our model simulating 1973 operations provided the short-term results as restricted by existing refinery capacity limitations while the simulation of the 1980 situation determined the long-term operating and investment cost considerations to provide supply.

B. SUMMARY OF RESULTS

For current (1973) operations our results concluded that up to 60% of the refinery gasoline pool could be supplied as lead-free gasoline at 91/83 RON/MON (Research Octane Number/Motor Octane Number) meeting the new, more restrictive volatility requirements with no gasoline yield debit. The increased gasoline manufacturing cost that can be attributed to supplying this special grade was less than 0.5 CPG.

Our results also showed that up to 80% of the total gasoline pool could be produced as a lead-free grade meeting present volatility standards with no decrease in total gasoline production volume and at essentially no increased manufacturing cost.

When gasoline octane specifications (particularly motor number, which was the limiting specification in all cases of substantial lead-free gasoline production) are increased, there is a rapid loss in production volume and an associated exponential increase in manufacturing cost.

The model results for future (1980) operations were essentially the same as for the current environment. At low octane specifications there were no manufacturing problems in maintaining full supply of lead-free gasolines and only nominal increases in manufacturing cost.

Compared with the 1973 cases, future operations which allow increased processing flexibility produced higher yields of lead-free gasoline at increased octane specifications. However, it was still not possible to meet the highest standards proposed because it is very difficult to increase clear motor octane number with present refining technology.

The results of this study also indicated that as long as octane specifications are maintained at moderate levels, the refining capital investments to produce lead-free motor gasolines are small in comparison with the magnitude of total investments needed to supply the industry's 1980 product requirements. For example, we estimate that production of 100% of the gasoline pool as lead-free 91/83 RON/MON product at existing volatilities will require a total refinery capital expenditure by 1980 of $17.2 billion versus $15.0 billion if the present gasoline grade structure is maintained, or a net increase of about 15%.

Most of the 1980 model runs assumed a delivered cost for imported high sulfur crude oil of $7/barrel. We also made a series of runs at higher crude prices which showed little effect on the differential costs for producing lead-free gasolines.

C. CONCLUSIONS

The results of this analysis are not substantially different from other studies made of this subject. They show that the large, flexible and efficient refineries which supply perhaps 90% of U.S. motor gasoline manufacture will suffer little yield or cost penalties associated with making large volumes of lead-free gasoline at the relatively low octane numbers now being proposed by GM. Of course it has been pointed out many times that simplified, fully-optimized refinery models will simulate operating and blending efficiencies that can not be achieved in the "real" world. However, the sophisticated long- and short-range planning functions of the major oil companies have evolved to the point where optimum profitability programs can be approached, especially when supplemented by product and component exchanges between refineries. Accordingly, we believe that the essential results of this study (i.e., that a 91/83 RON/MON lead-free gasoline at existing volatilities can be produced with minimum yield and economic penalty) are valid.

It is recognized that an overview study of this type, in which the entire U.S. refining industry is combined into one composite model refinery, will result in minimum operating penalties. In order to more closely represent the "real" world, it would be necessary to subdivide the total U.S. into logical refining regions which could be differentiated by crude supply patterns, product demands/ specifications, refinery processing options and associated regional capital and operating cost differentials. The results of such a more detailed study would pinpoint possible local problems (such as the U.S. West Coast) and would bring the overall analysis closer to the "real" world situation. We do not believe, however, that the regional analysis would reverse the trends and conclusions noted in this overview.

It should also be noted that the smaller, less efficient refineries operating in the United States under special logistic circumstances would suffer a more severe economic penalty for converting to low-lead gasolines. In addition, several other U.S. refineries producing primarily specialty products such as lubes or asphalts would be similarly penalized. Therefore, before "blanket" nationwide standards are unilaterally adopted to significantly revise U.S. motor gasoline specifications, some recognition should be given of the unique problems that will be experienced by these small refiners.

II. MODEL DATA INPUT

A. CURRENT OPERATIONS (1973)

1. Product Demands/Specifications

The product demand slate required for our simulation of the composite U.S. refining industry in 1973 was developed in the following fashion. We reviewed the 1972 statistics published in the January, 1973 *Mineral Industry Surveys* by the U.S. Bureau of Mines. Table I summarizes the U.S. refinery output for the year 1972 as presented in the referenced survey. We did not include in this tabulation refinery gases and other hydrocarbon streams used in own fuel consumption or catalytic cracking coke. These internal refinery streams are not required as data input to our simulation model but are developed internally by the model to maintain refinery material and energy balances.

Since the purpose of this project was to simulate the composite of those refineries producing the major portion of U.S. motor gasoline, we revised the basic Bureau of Mines data to prepare the input to our simulation model. There are several U.S. refineries which are operated to produce high yields of asphalt and/or lubes and low volumes of motor gasoline. Accordingly, we reflected the influence of these on the U.S. average in developing the simulated product demands from our composite "high gasoline yield" refinery.

Naphtha jet fuel (JP-4) normally contains about 30% of kerosene range boiling material and hence the kerosene jet fuel yield was increased to account for this volume. The naphtha portion of JP-4 was combined with other naphthas for such uses as petrochemical manufacture, BTX, solvents, etc. into one "general" naphtha category. We stipulated in the model that this "general" naphtha blend can only be supplied by full boiling range straight-run naphtha from the crude unit. Since this total amounts to only about 4.4% of the overall refinery output, it was felt that this consolidation was satisfactory. A more rigorous analysis would have treated each of the naphtha product categories separately with associated specifications and allowable blending components.

Two products from U.S. refineries are currently supplied primarily from sources other than domestic U.S. refining. These are LPG and low-sulfur residual fuel oil. Thus we felt it was not necessary that our simulation produce exactly the same historical volume yields of these products but instead allow volume elasticity at prices set by the alternative supply sources. These are LPG from natural gasoline plants (@ 8 CPG) and low-sulfur fuel oil imports from the Caribbean (@ $4.25/Bbl). However, we did set minimum volume requirements for each of these products at approximately 75% of their historical production levels.

TABLE I

U.S. REFINERY OUTPUT – 1972

Product	MM Bbls	%
Gasoline (Includes Aviation)	2,316	51.1
Jet Fuel - Naphtha	77	1.7
– Kerosene	233	5.1
Ethane	9	0.2
LPG	121	2.7
Kerosene	79	1.7
Distillate Fuel Oil (Includes Diesel)	962	21.2
Residual Fuel Oil	293	6.5
Petrochemical Feeds (Minus Gases)	109	2.4
Special Naphthas	32	0.7
Lubes and Wax	71	1.6
Coke (Market)	67	1.5
Asphalt and Road Oil	163	3.6
Total	4,532	100.0

Source: U.S. Bureau of Mines, *Mineral Industry Surveys*, January 1973.

Table II contains the product demands/specifications for 1973 operations which were used as input into our base case. It can be noted that most of the volume units shown for each product (the sum of these volume units outputs should be approximately 100) correspond to the actual 1972 outputs in the previous table. Since our "model" refinery makes less asphalt than the U.S. industry average, we have increased coke production to reflect the additional conversion of residual fractions to gasoline. Our choice of 25.0 volume units of premium gasoline (which results in 49% premium on total gasoline) was based on statistics provided in the *1973 National Petroleum News Factbook* issue. The percentage of premium sales for the important metropolitan areas in the U.S. are tabulated on page 79 of this publication and when weighted by the number of retail outlets for each area results in 47.2% premium in 1972.

2. Crude Oil Supply

The input to U.S. refineries for 1972 was obtained from the same January, 1973 *Mineral Industry Surveys* by the U.S. Bureau of Mines which was used for obtaining the refinery output shown in Table I. Table III summarizes the U.S. refinery input for the year 1972. Note that the column headed "percent" is based on the 4,532 MMBbls of total products as developed in Table I.

TABLE II

PROOUCT OEMANDS/SPECIFICATIONS
ADL MODEL INPUT – (1973 OPERATION)

Product	Volume Units*	Key Specifications
LPG	Min. 2.0	
Premium Gasoline	25.0	RON-Min. 100, MON-Min. 92 RVP-Max. 10, TEL-Max. 3.0
Regular Gasolina	25.0	RON-Min. 94, MON-Min. 86 RVP-Max. 10, TEL-Max. 3.0
Lead Free Gasoline	1.1	RON-Min. 92, MON-Min. 84
Naphtha	4.4	
Jet Fuel (Kerosene Range)	5.6	Sulf-Max. 0.1, API Gravity-Max. 46
Kerosene	1.7	Sulf-Max. 0.1, API Gravity-Max. 46
Diesel Fuel	5.0	Sulf-Max. 0.2
No. 2 Fuel Oil	16.1	Sulf-Max. 0.2
Low Sulfur Fual Oil	Min. 4.0	Sulf-Max. 0.5
High Sulfur Fuel Oil	1.0	
Lube 8ase Stocks	1.3	
Asphalt	2.5	
Petroleum Coka	1.7	
	Min. 96.4	

*To give approximately 100.0 total output

TABLE III

U.S. REFINERY INPUT – 1972

Material	MMBbl	%*
Domestic Crude	3,474	76.7
Foreign Crude	807	17.8
Unfinished Oils	52	1.1
LPG (8utanes)	85	1.9
Natural Gasoline	164	3.6
Plant Condensates	53	1.2
Other	10	0.2
Total	4,645	102.5

*Basis: 4,532 MMBbls Products shown in Table I.

Source: U.S. Bureau of Mines, *Minerl Industry Surveys*, January 1973.

NPRA Special Report Number 3 entitled *U.S. Domestic Petroleum Refining Industry's Capability to Process Sweet/Sour Crude Oil* indicates that about two-thirds of U.S. domestic crude should be classified as sweet. The same publication indicates that about half of imported crude to the U.S. is sweet.

The refinery raw materials supply which we developed for our 1973 refinery model input is shown in Table IV. Note that the incremental crude oil used to balance the product slate was imported sour crude @ $3.75/Bbl. The availability of purchased natural gas was based on the latest historical information available which was for the year 1971 (Final Summary) published by the U.S. Bureau of Mines on December 20, 1972.

TABLE IV

REFINERY RAW MATERIAL SUPPLY
ADL MODEL INPUT – (1973 OPERATION)

Material	Volume Units*	Price – $/BBL
Domestic Sweet Crude Oil	45.0	–––
Domestic Sour Crude Oil	30.0	–––
Imported Sweet Crude Oil	12.0	–––
Imported Sour Crude Oil	To Balance	3.75
Natural Gasoline	3.5	–––
Normal Butane	max. 1.0	3.36
Isobutane	max. 1.0	3.78
Purchased Gas (F. O. E.)	max. 3.5	30¢/MSCF

* To give approximately 100.0 Total Output as defined in Table II.

For our overall average of U.S. refining runs the following crude oils were used to simulate the four basic categories: domestic sweet – Louisiana, domestic sour – West Texas, imported sweet – mixed Nigerian, imported sour – Arabian Light. The composite of these crudes in the proportions made available very closely approximates the average sulfur content and gravity of U.S. crudes charged to refineries as indicated in Table V. We allowed our model refinery to reduce purchases of normal butane, isobutane and natural gas, if profitable, at the price levels indicated in Table IV.

B. FUTURE OPERATIONS (1980)

1. Product Demands/Specifications

Since oil is only one of the major fuels consumed in the U.S., it is necessary to first determine what role oil will play in the total energy balance in 1980. To

TABLE V

CRUDE OUALITIES – ADL REFINERY SIMULATION 1973

Crude Type	% Volume	Gravity – °API	Sulfur – % w
Louisiana	45	36.2	0.2
West Texas	30	33.2	1.7
Mixed Nigerian	12	29.5	0.2
Arabian Light	13	34.5	1.7
Average of Above		34.1	0.7
1971 U. S. Average Production*		32.5	0.7

* Derived from data given in "Giant Fields" section of the *International Petroleum Encyclopedia.*

do this we divided the U.S. energy market into five primary energy consuming markets: residential/commercial, transportation, utilities, industry, and miscellaneous. For our base year (1972) we then determined the Btu's of energy and the primary form (coal, oil, natural gas, hydro-nuclear) each consuming market used. Applying the same growth rates assumed in the National Petroleum Council's "Initial Appraisal"[1] and in its intermediate demand case in the "U.S. Energy Outlook,"[2] we projected the total Btu's which would be required in 1980 by each consuming sector. Having forecasted the total number of Btu's required by each consuming sector, we then estimated the percentage share of the total Btu's in each sector which would be fulfilled by oil.

We actually determined a range of oil demands by examining the impact of three scenarios on the total demand for oil. Each of the three cases makes assumptions about the position which oil will hold in each market relative to oil's 1972 share. For example, in one case, which was designed to simulate a situation of maximum oil demand, oil was assumed to hold its 1972 position and absorb all of the growth in the residential/commercial, transportation and industrial markets. In the utility market, oil was presumed to not only maintain its share and assume all growth, but was assigned to replace all natural gas currently consumed by that sector. The other two scenarios explored a maximum nuclear case (in which oil growth is, therefore, minimal) and a moderate course in which oil participates in growth in energy demand in proportion to its 1972 market shares.

1. National Petroleum Council, "U.S. Energy Outlook: An Initial Appraisal 1971-1985," November 1971.
2. National Petroleum Council, "U.S. Energy Outlook," December 1972.

The product demand input to our ADL refinery model for 1980 base case operations is shown in Table VI. All product demands were fixed except LPG (which was allowed to sell above a minimum production level at $8.00 per barrel refinery netback) and low-sulfur residual fuel oil (which was allowed to produce up to a maximum of 15% volume at $9.00 per barrel). The residual fuel oil has a heating value approximately double that of LPG so there is a substantial "form" value premium for the LPG.

We considered two basic scenarios for grade distribution of the total gasoline pool in the base case. Scenario I assumed that there would not be widespread conversion to automotive engines equipped with catalytic afterburners requiring lead-free gasoline and that the present gasoline grade distribution would change only slightly to 47% premium gasoline and 6% lead free. Scenario II assumed that a major shift to a lead-free 92 octane gasoline would occur for 1975 and later models and that by 1980 the base case overall gasoline output would consist of 3% premium and 41% lead-free 92 RON.

This specification (92 RON) was chosen to represent the low lead grades currently being supplied and should not be considered a formal recommendation by GM.

We anticipate a reduction in petroleum coke production concurrent with the increased profitability for producing low-sulfur oil.

TABLE VI

PRODUCT DEMANDS
ADL MODEL INPUT – (1980 OPERATION)

Product	Volume Units*
LPG	Min. 2.5
Gasoline	49.1
Naphtha	3.0
Jet Fuel (Kerosene Range)	7.5
Kerosene	2.6
Diesel Fuel	5.0
No. 2 Fuel Oil	20.0
Low-Sulfur Fuel Oil	Max. 15.0
High-Sulfur Fuel Oil	1.0
Lube Base Stocks	1.3
Asphalt	2.5
Petroleum Coke	1.2

*To give approximately 100.0 Total Output.

2. Crude Oil Supply

The refinery raw material supply which we developed for our 1980 refinery model input is shown in Table VII. We assumed that the domestic crude oil total would approximate 50% of the crude slate, of which 60% was sweet. Again, imported sour crude oil was the incremental crude supply and in 1980 it was assumed to cost $7.00 per barrel, delivered. Although this may superficially appear low, this is a high-sulfur, poor quality crude oil and other crude oils which are valued in parity with this reference crude had much higher values (and presumed prices) calculated by the 1980 base case. The domestic sour crude oil (West Texas) was valued at $7.25 a barrel, the domestic sweet crude oil (Louisiana) was valued at $8.30 a barrel and the imported sweet crude oil (Nigerian mixed) was valued at $8.35 a barrel. However, to test the sensitivity of lead-free gasoline economics to crude price, we made some runs at higher crude prices ($10 a barrel for delivered Arabian light).

TABLE VII

REFINERY RAW MATERIAL SUPPLY
ADL MODEL INPUT – (1980 OPERATION)

Material	Volume Units	Price – $/Bbl
Domestic Sweet Crude Oil	30.0	
Domestic Sour Crude Oil	20.0	
Imported Sweet Crude Oil	10.0	
Imported Sour Crude Oil	To balance	7.00
Natural Gasoline	2.0	
Normal Butane	Max. 1.0	8.00
Isobutane	Max. 1.0	8.50

We anticipated that normal and isobutane purchase prices would be consistent with the refinery netback price for LPG (mostly propane) and reflect market premiums for these products due to decreased availability of natural gas liquids. Thus, we allowed our 1980 refinery to purchase normal butane and isobutane at prices of $8.00 per barrel and $8.50 per barrel respectively. Propane (@ $8.00 per barrel) has a lower heating value than either normal butane or isobutane. We assumed that the availability of natural gasoline would decrease from 3.5% volume to 2% volume and that purchased natural gas would no longer be available for refinery use.

III. MODEL RESULTS

A. CURRENT OPERATIONS (1973)

1. Base Case

The optimized refinery material balance for the base case is shown in Table VIII. It can be seen that the model did not find it economically attractive to process as much incremental crude oil (imported sour at $3.75 per barrel) and make as much LPG (at 8 CPG) and low-sulfur residual fuel oil (at $4.25 per barrel) as the 1972 actuals.

TABLE VIII

REFINERY MATERIAL BALANCE
1973 BASE CASE
VOLUME %

Intakes	1973
Domestic Sweet Crude Oil	46.42
Domestic Sour Crude Oil	30.94
Imported Sweet Crude Oil	12.38
Imported Sour Crude Oil	5.54
Natural Gasoline	3.61
Normal Butane	1.03
Isobutane	1.03
Purchased Gas (F.O.E.)	3.61
Total	104.56
Outturn	**1973**
LPG	2.06
Premium Gasoline	25.79
Regular Gasoline	25.79
Lead-Free Gasoline	1.13
Naphtha	4.54
Jet Fuel	5.78
Kerosene	1.75
Diesel Fuel	5.16
No. 2 Fuel Oil	16.60
Low-Sulfur Fuel Oil	4.70
High-Sulfur Fuel Oil	1.03
Lube Base Stocks	1.34
Asphalt	2.58
Petroleum Coke	1.75
Total	100.00

A simplified refinery flow diagram of the processing sequence selected for the base case is given in Figure 1. A detailed description of the model operation and the development of technical refining data used as input for these runs is given in the appendix to this report. Of special interest is the variation of feed capacity limitations for conversion units, such as catalytic cracking and reforming, as a function of processing severity. For example, if it is desired to increase the catalytic cracker conversion from 65 to 85% on an existing unit at feed capacity, it is necessary to reduce intake by 5%.

Table IX provides a comparison between the processing unit intakes selected by the model for the 1973 base case operation and the individual unit capacity limits reported in the April 2, 1973 *Oil and Gas Journal.* Our optimized composite refinery checked fairly well against existing unit limitations. There are some refineries which charge atmospheric crude distillation column bottoms directly to thermal operations instead of via vacuum distillation. This is one reason why our vacuum distillation intake is slightly higher and thermal intake lower than industry capacity. The catalytic reforming intake required by the model was lower than industry capacity available, reflecting the more efficient octane improvement inherent in a completely optimized system. It also reflects the simplification of treating BTX manufacture only as a debit from the general naphtha pool and thus not requiring reforming capacity to produce. We estimate that including BTX with reformate production would add 2 to 3% to reformer intake. Since we are examining delta yield and economic effects from an optimized base case, the deviation caused by this simplification is not significant.

TABLE IX

1973 BASE CASE REFINING SIMULATION
U.S. PROCESSING CAPACITY

Unit	Capacity*	Model Result
Crude Distillation	100.0	100.0
Vacuum Distillation	36.8	39.7
Catalytic Reforming	26.6	18.5
Catalytic Cracking	32.2	30.6
Hydrocracking	6.2	5.1
Alkylation	5.8	6.3
Thermal Operations	10.3	5.1

*Basis *Oil and Gas Journal* – April 2, 1973.

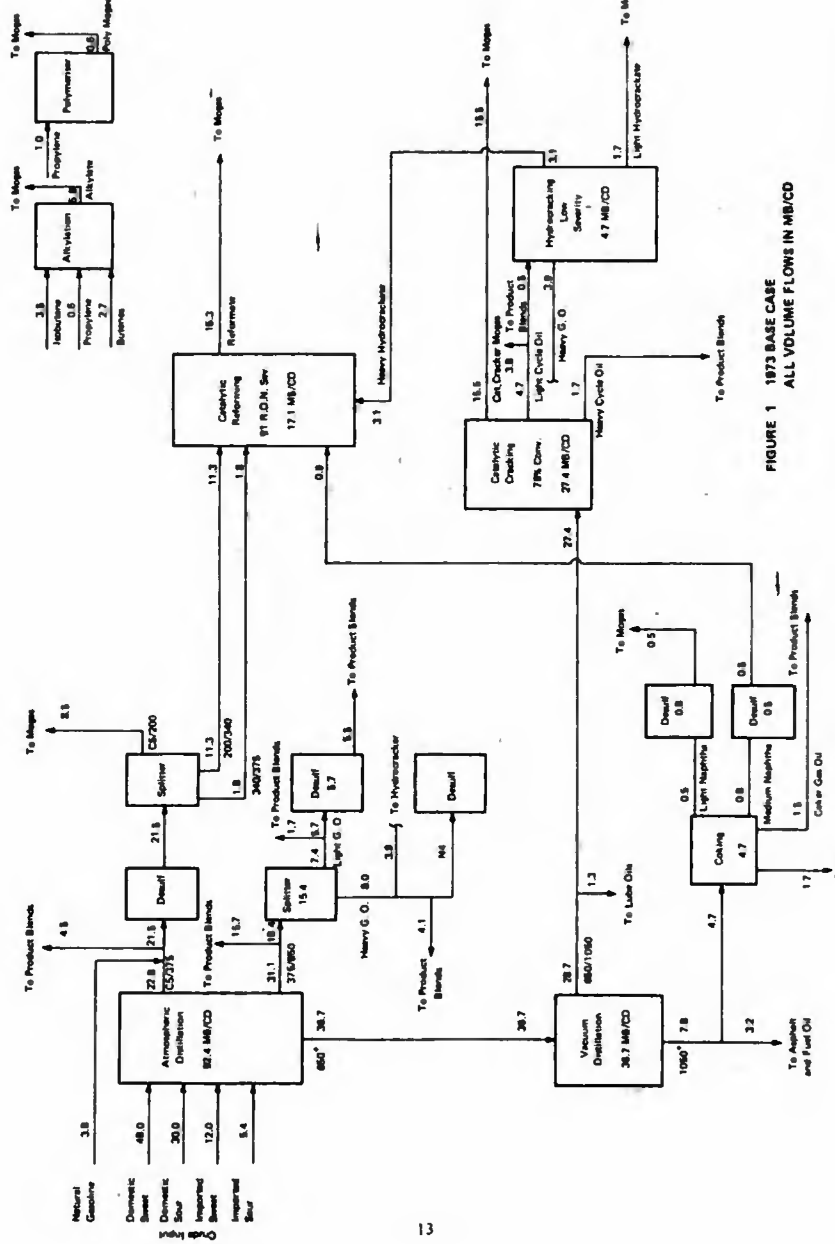


FIGURE 1 1973 BASE CASE
ALL VOLUME FLOWS IN MB/CD

2. Parametric Runs

The processing unit capacities calculated as required for the optimized base case refinery were then submitted as data input to limit maximum processing unit intake availabilities for all subsequent 1973 runs. We then systematically increased the yield and octanes of lead-free gasolines both with the new proposed volatility specifications and with existing volatilities. The proposed new GM volatility specifications are:

10% evaporated, ° F	140 ± 10
50% evaporated, ° F	200 ± 10
90% evaporated, ° F	300 ± 10
endpoint, ° F	365 maximum
Reid vapor pressure	8-9

The first set of parametric runs consisted of increasing volume yields of a 91/83 RON/MON unleaded gasoline at the proposed new GM volatilities. The gasoline yield penalty associated with producing this grade of gasoline is presented in Figure 2. It can be seen that up to 60% of the total gasoline pool can be produced as a lead-free 91/83 RON/MON new volatility product with no yield debit in our simulated refinery. Processing unit intakes were limited to base case availability (with appropriate capacity adjustments made for changes in operating severity). When the entire refinery gasoline pool is produced as a lead-free GM grade, gasoline output was reduced to 90% of the base case level. If, however, the gasoline is allowed to meet *existing* volatility specifications, then up to 80% of the pool can be produced as lead-free grade with no yield penalty. When the pool was increased to 100% lead-free, nearly 99% of base case gasoline production can be maintained.

Figure 3 provides a simplified flow diagram of the case producing 100% of the gasoline pool as a lead-free grade, but at existing volatility specifications. It should be noted that this case produced 99% volume of the total base case gasoline. The key processing differences were an increase in reforming severity to 97 clear RON from 91 (at a reduction in feed rate from 17.1 to 16.7 MB/CD) and an increase in catalytic cracker conversion from 78 to 85% (at a reduction in feed rate from 27.4 to 26.9 MB/CD).

Figure 4 provides the economics associated with the parametric case of increasing lead-free gasoline yield at 91/83 RON/MON. The base case operation indicated that a 13.8 CPG composite refinery gasoline netback was required to cover all raw material costs, refinery operating expenses, and a 20% before-tax return on capital investment, less by-product credits. For all parametric cases the individual unit raw material costs and by-product credit price levels were kept constant, including the balance of the conventional motor gasoline pool. All

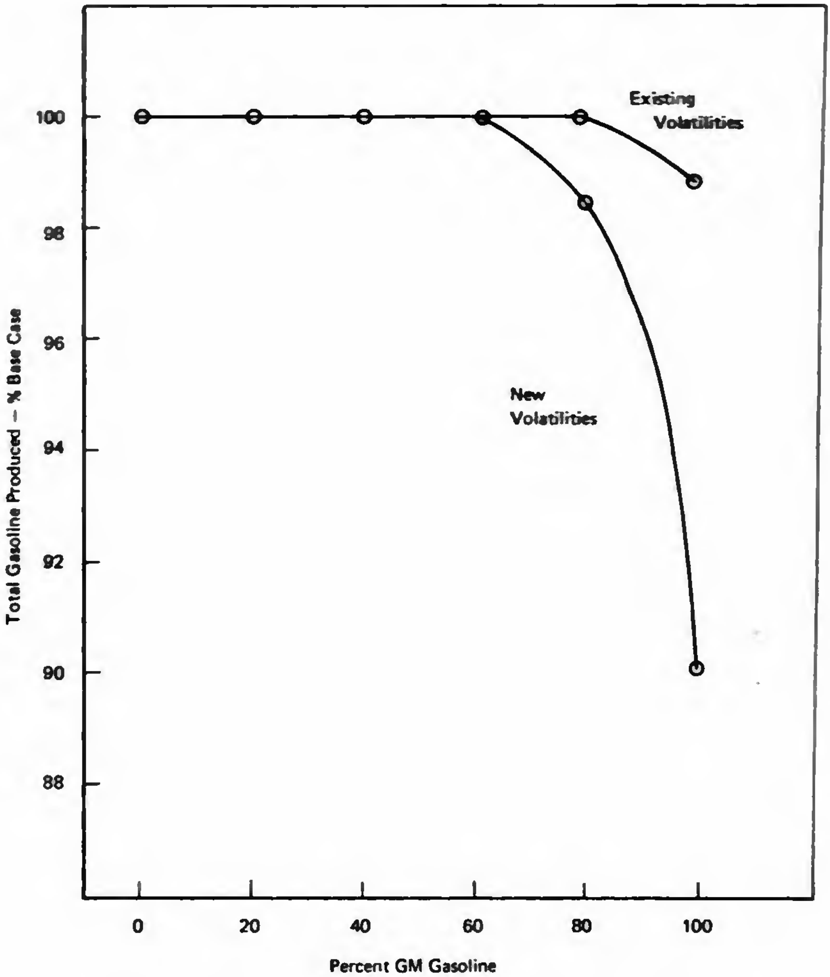
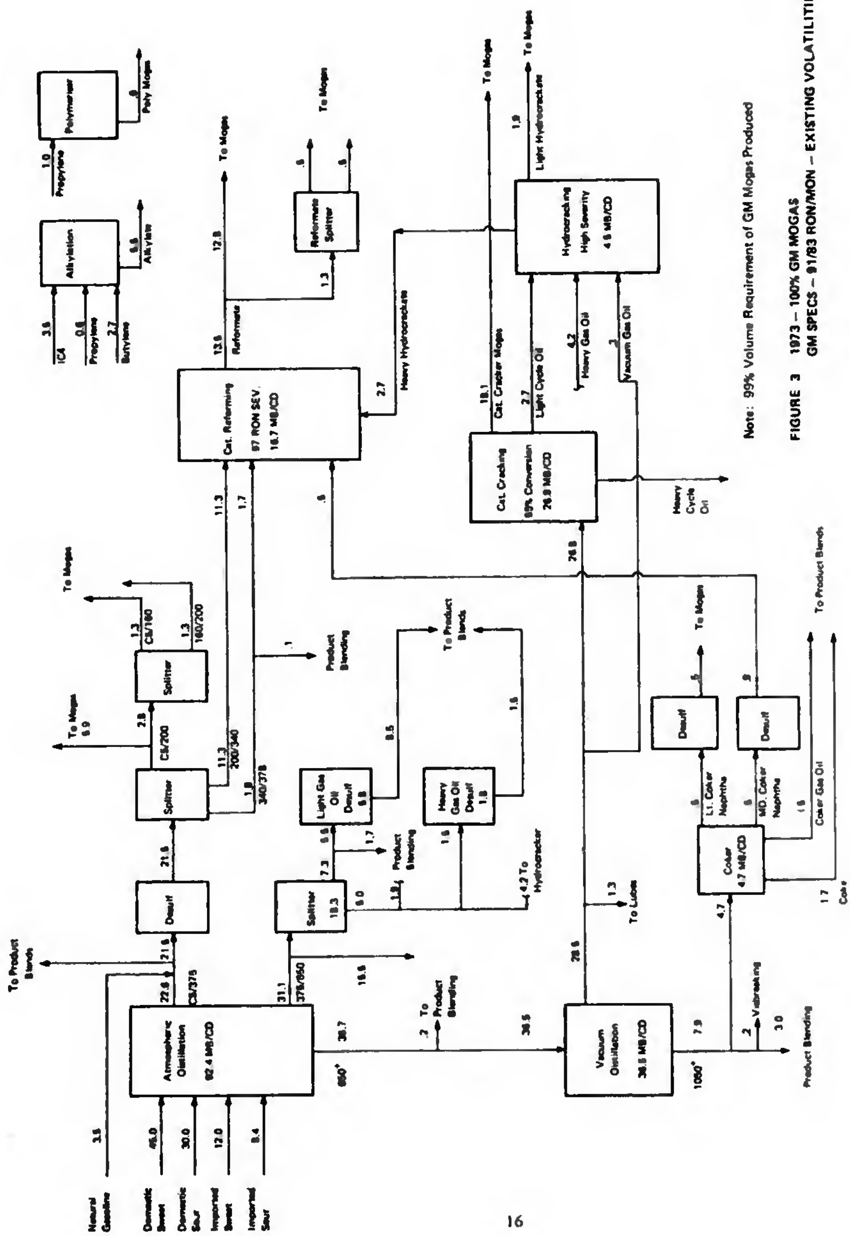


FIGURE 2 1973 OPERATIONS – TOTAL GASOLINE PRODUCTION VERSUS PERCENT GM GASOLINE
(Existing and New Volatilities – RON–91/MON–83)



Note: 99% Volume Requirement of GM Mogas Produced

FIGURE 3 1973 – 100% GM MOGAS
GM SPECS – 91/83 RON/MON – EXISTING VOLATILITIES

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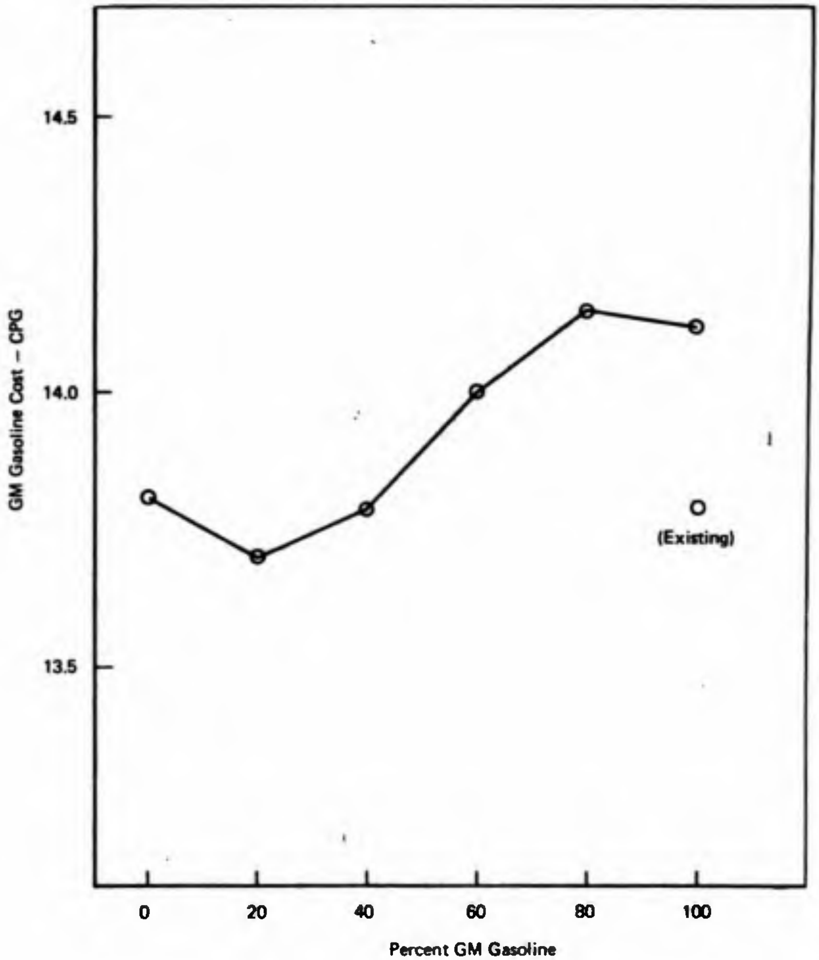


FIGURE 4 1973 OPERATIONS – GM GASOLINE COST VERSUS PERCENT GM GASOLINE (New Volatilities – RON–91/MON–83) credits or debits due to changes in refinery purchased raw materials, refinery capital and operating costs, and by-product production levels were reflected in the value of the new GM gasoline grade.

It should be noted that the initial production volume of lead-free gasoline can be produced at less cost than the balance of the conventional refinery pool. This is because of the wide variations in octane/lead susceptibility among the various gasoline blending components. The optimization of refinery reforming operations/lead additions is determined using the average susceptibility of each product grade. When it is desired to make a small percentage of the pool as a separate lead-free grade and use those components least susceptible to lead additions in this grade, there is an economic benefit. However as expected, when the percentage of lead-free grade increases to about 40%, there is an economic debit associated with producing this product. The slight decrease in gasoline cost between the 80 and 100% levels reflects the reduction in gasoline yield due to processing unit bottlenecks rather than a discontinuity in fundamental supply economics.

We have also shown in Figure 4 the cost for producing 100% unleaded gasoline at existing volatilities, which is essentially the same as the base case cost. The increased refinery processing required to raise the pool clear motor octane number from the base case level of 81.6 to 83 is essentially offset by eliminating the lead additive costs.

The conclusions from this set of parametric runs should not be surprising since similar studies have indicated that there are no severe economic or yield penalties associated with producing lead-free gasolines of about the 91/83 RON/MON level.

Another significant point is that the base case leaded gasolines each had about an 8 octane sensitivity (i.e., RON minus MON). However, when lead is removed from the refinery pool, motor octanes decrease faster than research and thus become the limiting specification. For example, in catalytic reforming, increasing severity to raise clear research octane number 12.0 units will increase clear motor octane number only 7.9 units. Thus, in order to meet the 83 MON at 100% GM gasoline and the new volatilities, a research octane number of 92.7 (or a "giveaway" of about 1.7 research octane units) was required. This phenomenon continued throughout the remainder of the 1973 and 1980 runs.

In the next set of parametric runs, 30% of the total gasoline pool was produced as lead-free grades, again at both new and existing volatilities. It was felt that this 30% case was an important scenario to examine in that if new standards are imposed on the U.S. refining industry, it will take about three years before major additions to processing units can be made. Thus up to 30% of the pool could be required as the new grades from refineries which are still limited by existing processing capability. For these runs we successively increased octane numbers from 91/83 RON/MON to 99/91 for the unleaded grades. Figure 5 indicates the yield reduction penalty for producing the GM grades as motor octane number is increased. It can be seen that up to 85 clear octane number can be produced at the new volatilities with no yield penalty, while up to 87 octane can be produced at existing volatilities with no yield debit. Figure 6 is essentially the same as Figure 5 except that the entire yield reductions are reflected on the lead-free GM grade rather than the total gasoline pool and thus the magnitudes are more severe.

Figure 7 indicates the gasoline costs for producing the new unleaded grades at the higher motor octane numbers. As expected, there are significant increases in gasoline costs with the higher motor octane numbers.

The last set of parametric runs for 1973 operations was at 100% unleaded gasoline production at increasing motor octane number. Figure 8 shows the yield decline as octane number is increased. For the existing volatility cases, the model could make up to 86 clear motor octane number before becoming infeasible. At the new volatilities, 83 was the maximum clear motor octane number possible. Figure 9 presents the economics for these runs. Increasing clear motor octane number from 83 to 86 at existing volatilities will cost about 2 CPG in the 1973 base case refinery.

Figure 10 shows the simplified refinery processing sequence for producing 30% unleaded gasoline at the new proposed GM volatilities and 97/89 RON/MON. The major differences from the 1973 base case are increases in reformer severity from 91 to 96 and catalytic cracker conversion from 78 to 85. To make 30% of the pool at 365° F max. endpoint (E.P.), the following steps were taken. Reformer feed E.P. was lowered from 375 to 340° F to produce a low E.P. reformate blend stock for the GM grade. Both straight-run and heavy hydrocracked feed stocks were adjusted. A portion of the full range catalytic cracked gasoline was "re-run" to produce a low E.P. blend component.

B. FUTURE OPERATIONS (1980)

1. Base Case

The initial base case run for 1980 adopted Scenario 1 described in the product demand section (i.e., assuming the continuation of present grade mix of premium and lead-free gasoline within the gasoline pool). For this case the model calculated a composite gasoline netback of 25.26 CPG required to cover raw material costs, refinery operating expenses and capital recovery, less by-product credits.

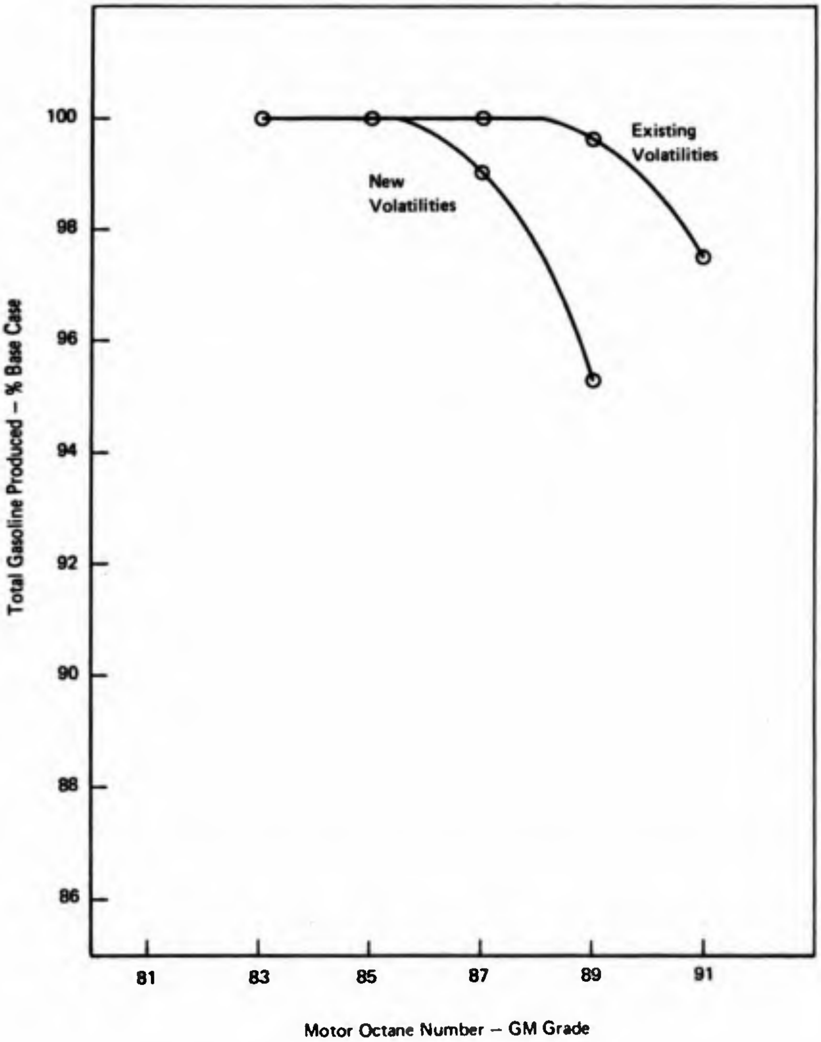


FIGURE 5 1973 OPERATIONS – TOTAL GASOLINE PRODUCTION VERSUS MOTOR OCTANE NUMBER – GM GRADE
(Existing and New Volatilities – GM Gasoline: 30%)

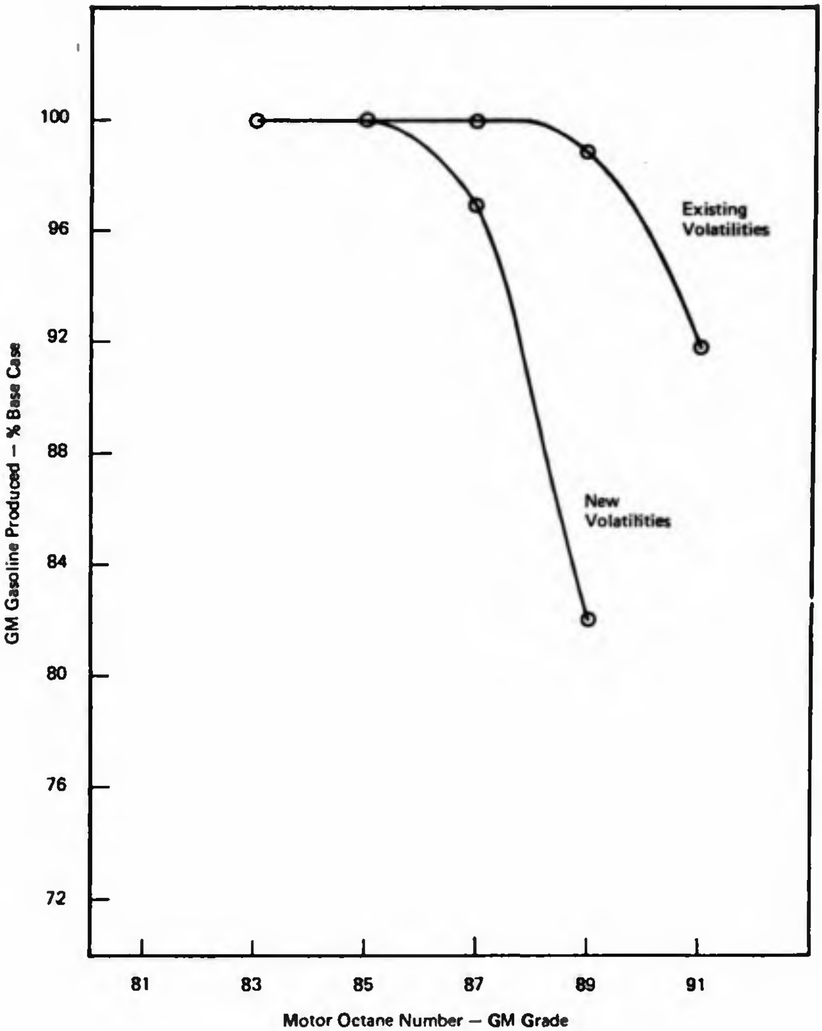


FIGURE 6 1973 OPERATIONS – GM GASOLINE PRODUCTION VERSUS MOTOR OCTANE NUMBER – GM GRADE
(Existing and New Volatilities – GM Gasoline: 30%)

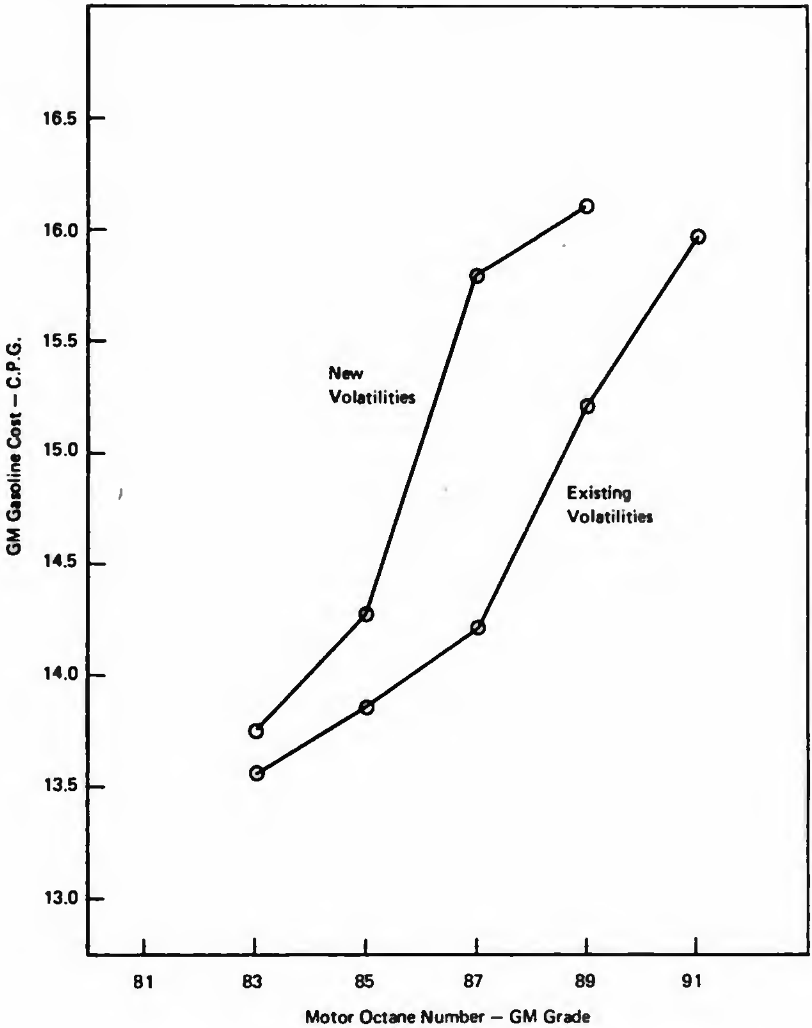


FIGURE 7 1973 OPERATIONS – GM GASOLINE COST VERSUS MOTOR OCTANE NUMBER – GM GRADE
(Existing and New Volatilities – GM Gasoline: 30%)

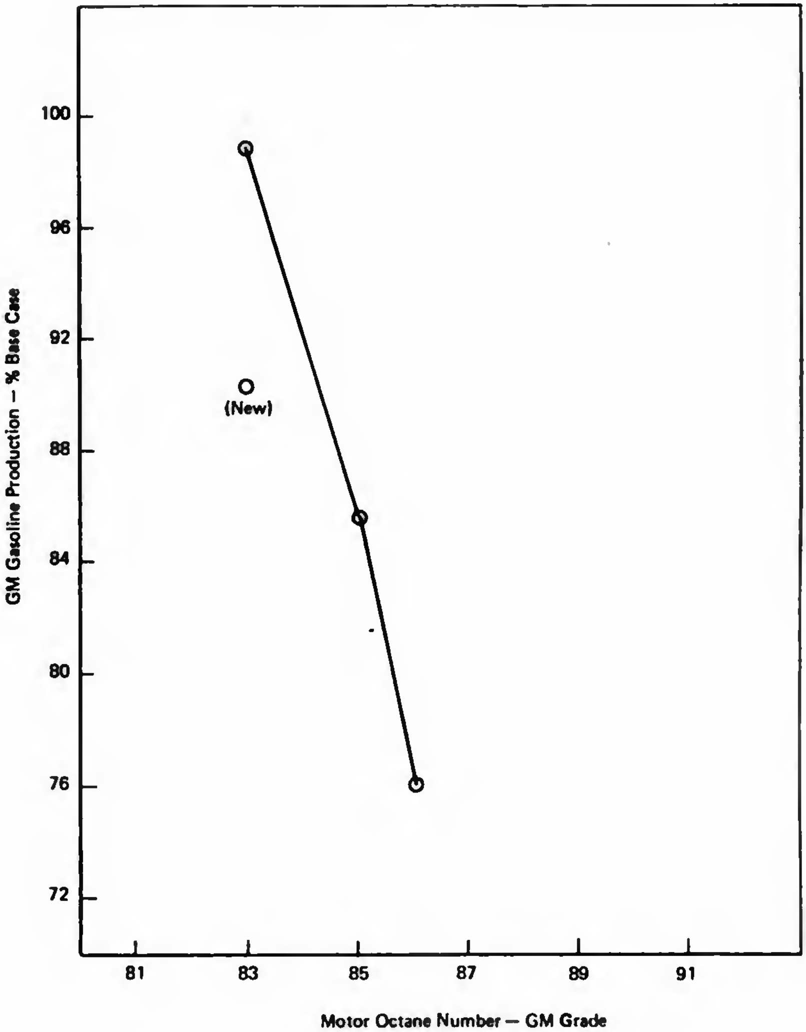


FIGURE 8 1973 OPERATIONS — GM GASOLINE PRODUCTION VERSUS MOTOR OCTANE NUMBER — GM GRADE (Existing Volatilities — GM Gasoline: 100%)

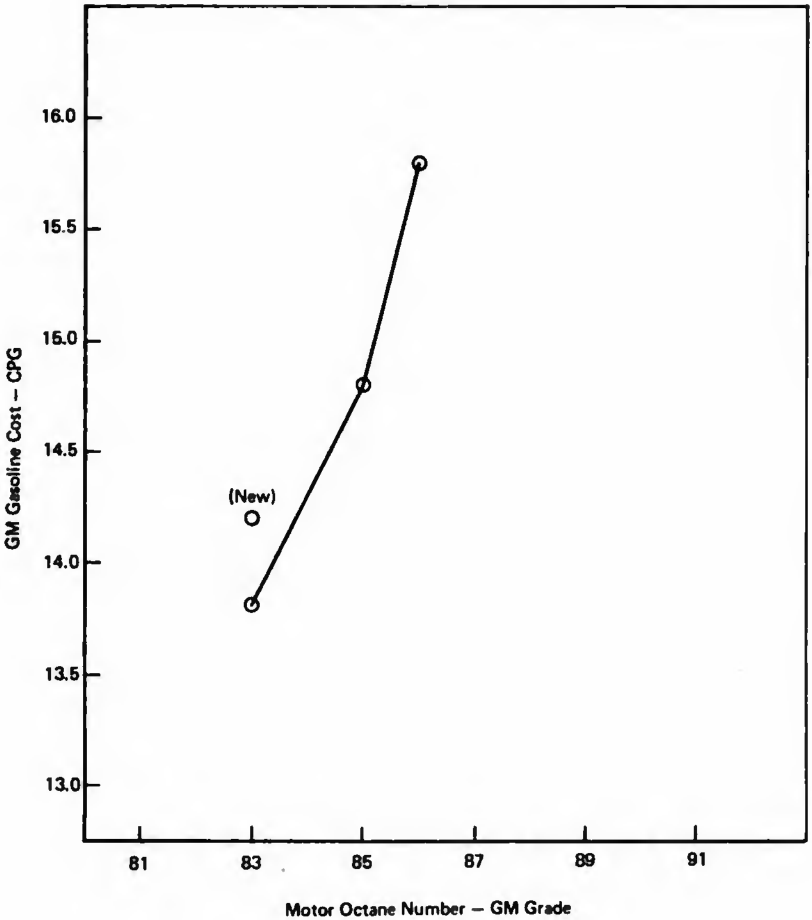
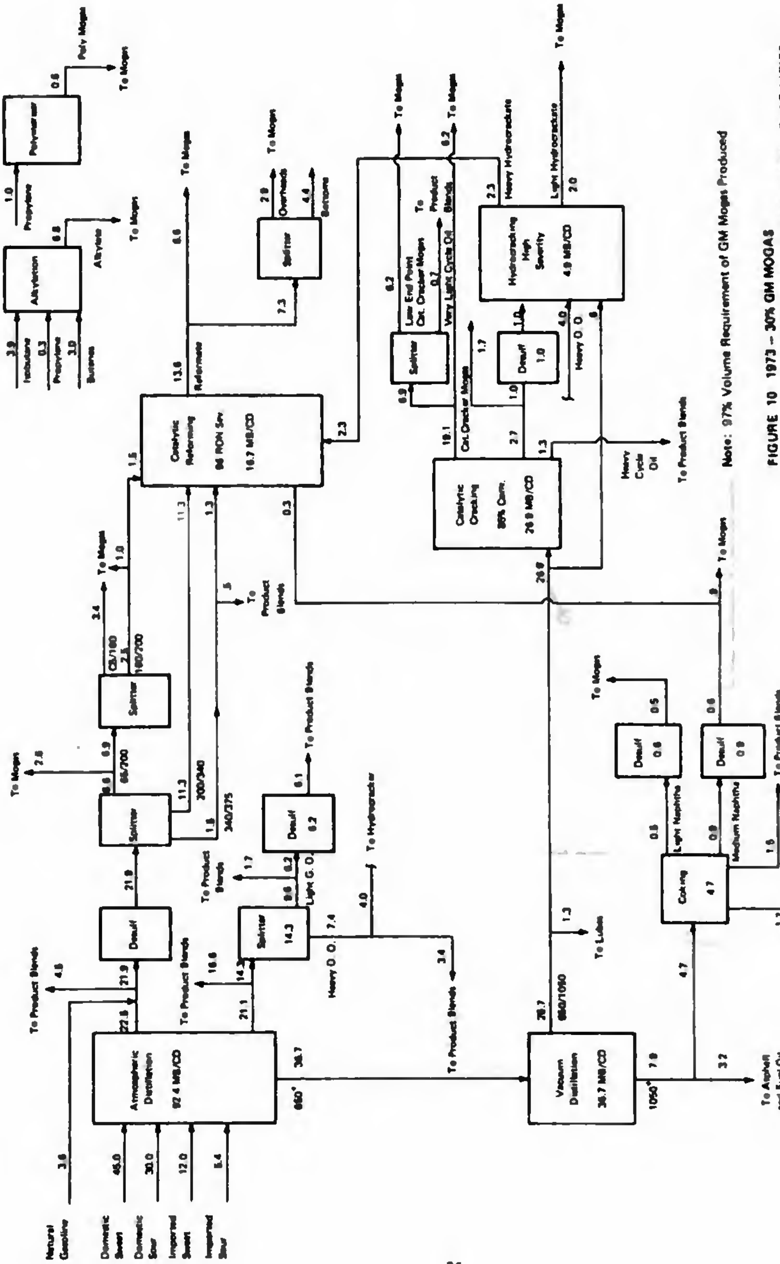


FIGURE 9 1973 OPERATIONS – GM GASOLINE COST VERSUS MOTOR OCTANE NUMBER – GM GRADE (Existing Volatilities – GM Gasoline: 100%)



Note: 97% Volume Requirement of GM Mogas Produced

FIGURE 10 1973 – 30% GM MOGAS
GM SPECS – 97/89 RON/MON – NEW VOLATILITIES

The alternative base case as described in Scenario II in the product demand section (i.e., the gasoline pool in 1980 will require essentially no premium gasoline and a high volume of lead-free product) resulted in a composite gasoline manufacturing cost of 25.00 CPG or a reduction of only 0.26 CPG from the other alternative. Since this scenario essentially replaced a leaded 100/92 product with an unleaded 92/84 grade, there was little change in refinery processing. The primary reason for the reduced manufacturing cost of the composite pool was due to the large reduction in purchased lead.

Table X presents the refinery material balance for the 1980 base case under the first scenario. It can be seen that the model found it attractive to produce a higher volume of marginal LPG than the minimum specified, and also to make the maximum allowable volume of low-sulfur residual fuel oil. A simplified refinery flow diagram for this base case is shown in Figure 11. There is a reduction in catalytic cracker intake and conversion versus the 1973 case, but increases in catalytic reforming intake and severity and hydrocracking operations. The higher concentration of sour crudes caused increased distillate desulfurization as well as the introduction of catalytic cracker feed and residual fuel oil desulfurization.

2. Parametric Runs

The first set of parametric runs was made by systematically increasing production of a 91/83 RON/MON lead-free gasoline at both the new and existing volatilities. Allowing flexibility to incorporate new refinery processing equipment, it was possible to maintain 100% of the base case gasoline production at these moderate octane levels for all cases. Figure 12 shows the increased manufacturing cost associated with producing an increasing percentage of lead-free gasoline. As in the 1973 runs, it is possible to manufacture essentially 100% lead-free gasoline at low octanes with no significant increase in cost. Again it should be noted that the motor octane number was the limiting product specification at the high percentage of lead-free supply. For example, in the 100% lead-free gasoline case with new volatilities, the research octane number was 93.6, or a "giveaway" of 2.6 octane units.

Figure 13 shows a simplified refinery flow diagram for producing 100% GM gasoline at 91/83 RON/MON and existing volatility. This case produced exactly the same volume of motor gasoline as the 1980 base case but required an additional 1.2 unit volumes of crude oil. However, there was an offsetting increased production of 1.4 volume units of LPG (the only product outturn allowed to vary). Although the lead-free gasoline consumed more crude oil, an offsetting credit must be given for the increased supply of LPG which carries a premium form value in the marketplace. The significant changes in refinery processing sequence from the base case include a substantial increase in catalytic reforming feed from 22.6 to 27.0 MB/CD and an increase in severity from 95 to

TABLE X

REFINERY MATERIAL BALANCES
1980 BASE CASE
VOLUME %

Intakes	1980
Domestic Sweet Crude Oil	26.97
Domestic Sour Crude Oil	17.98
Imported Sweet Crude Oil	8.99
Imported Sour Crude Oil	49.14
Natural Gasoline	1.80
Normal Butane	–
Isobutane	–
Purchased Gas (F.O.E.)	–
Total	104.88

Outturn	1980
LPG	2.72
Premium Gasoline	20.68
Regular Gasoline	20.68
Lead Free Gasoline	2.79
Naphtha	2.70
Jet Fuel	6.74
Kerosene	2.34
Diesel Fuel	4.50
No. 2 Fuel Oil	17.97
Low Sulfur Fuel Oil	13.48
High Sulfur Fuel Oil	.90
Lube Base Stocks	1.17
Asphalt	2.25
Petroleum Coke	1.08
Total	100.00

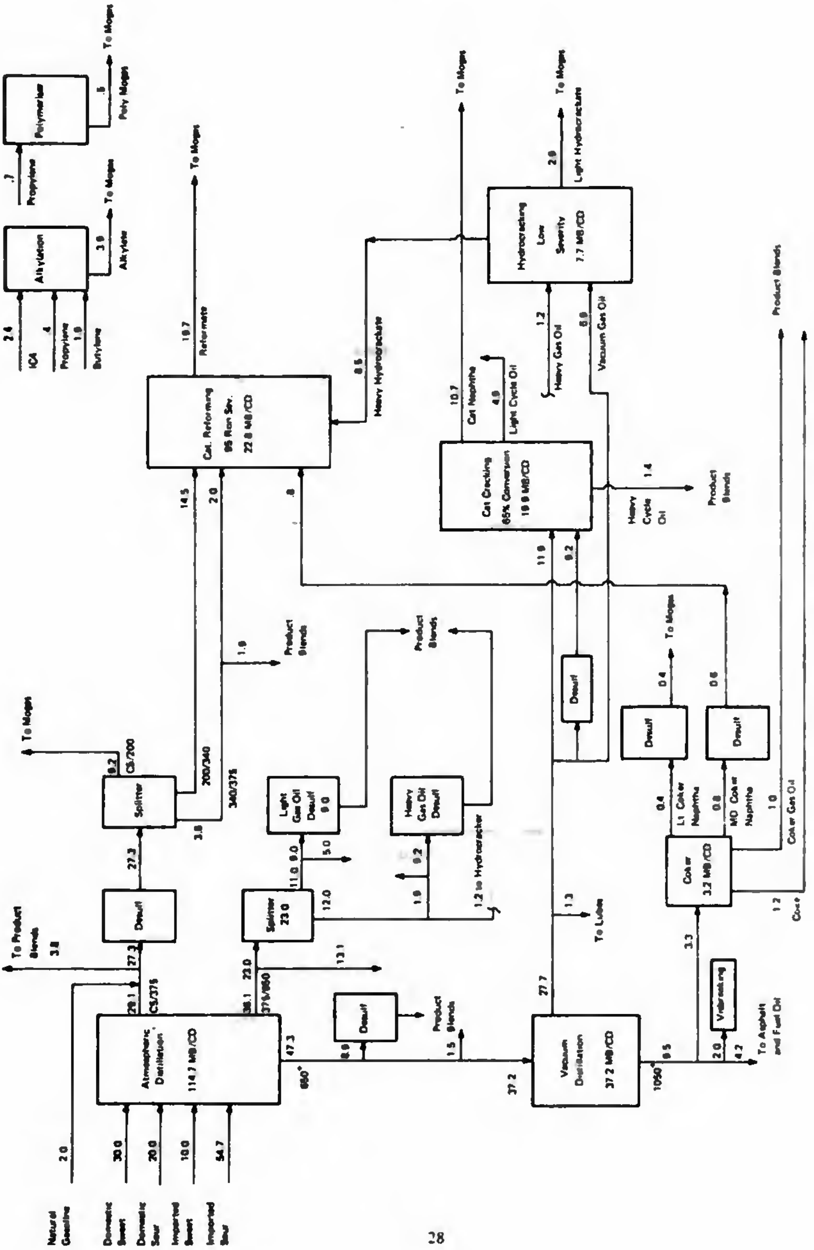


FIGURE 11 1980 BASE CASE
ALL VOLUME FLOWS IN MB/CD

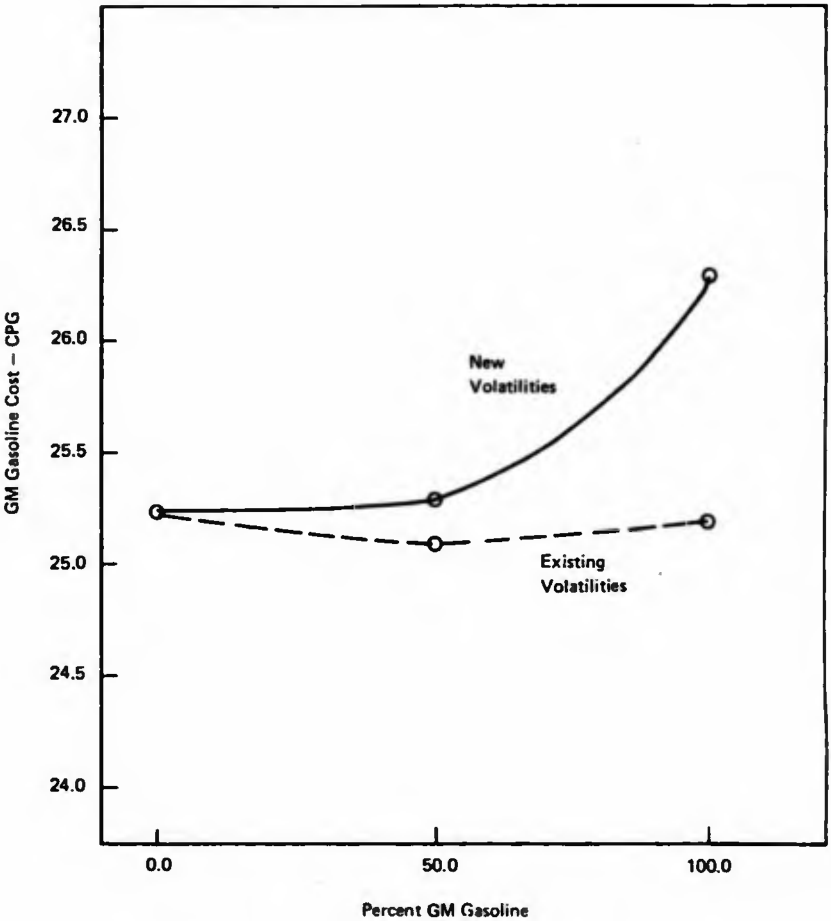


FIGURE 12 1980 OPERATIONS – GM GASOLINE COST VERSUS PERCENT GM GASOLINE
(Existing and New Volatilities – RON–91/MON–83)

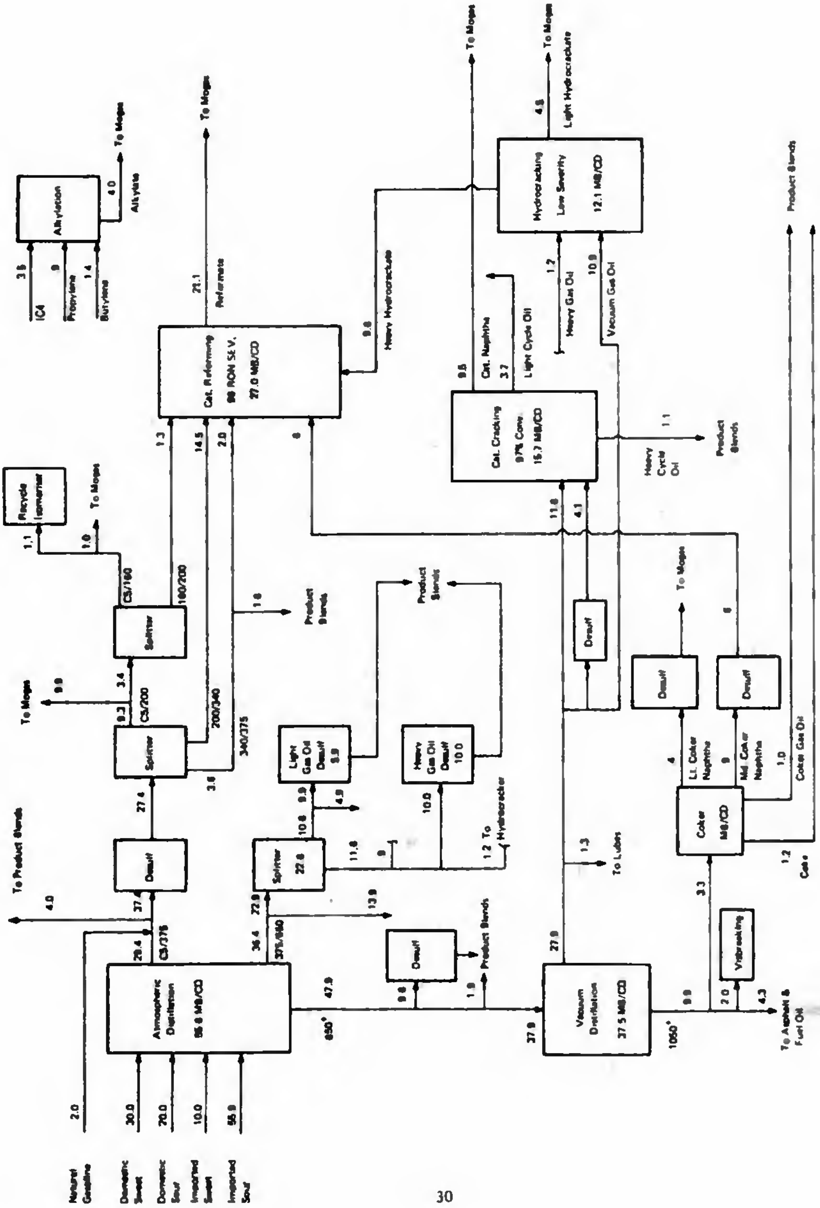


FIGURE 13 1980 – 100% GM (91/83 RON/MON)
EXISTING VOLATILITIES

99 RON. Catalytic cracker make decreased from 19.8 to 15.7 MB/CD with an offsetting increase in hydrocracking feed from 7.7 to 12.1 MB/CD. Polymerization operations were discontinued and all olefins were alkylated. All these operating changes are consistent with the need to increase clear motor octane number which is required with the removal of lead. The other major processing change was the introduction of C5/C6 isomerization, another process which becomes attractive at reduced lead levels due to the high lead susceptibility of light straight-run blend stocks.

The next set of parametric runs was made with 50% of the refinery gasoline pool being supplied as GM grade gasoline at both the new and existing volatilities. The percent reduction of total gasoline make is shown in Figure 14 for increasing motor octane numbers of the lead-free grade. Up to 87 clear motor octane number can be made at the new GM volatilities and up to 89 clear motor octane number at existing volatilities before any yield decline occurs. Figure 15 shows the same results with the gasoline reduction reflected as percentage of the GM grade rather than the total pool, which doubles the magnitude of the decline.

Figure 16 shows the increased GM gasoline manufacturing costs with increasing motor octane number at 50% GM gasoline production. An increase of 8 motor octanes (from 83 to 91) results in an increase of nearly 7 CPG in manufacturing costs with existing volatility specifications.

Figure 17 is similar to Figure 16 and shows the increased GM gasoline manufacturing costs for new volatilities under the 1980 Scenario II base case. The 50% of the total gasoline pool treated as conventional grade structure contained only 3% premium and 41% 92/84 lead-free. The results of this series of runs essentially duplicated those starting from the Scenario I base case.

The next set of parametric runs was at 100% GM gasoline production at increasing motor octane number. In this series of runs the change from feasible to infeasible operation as a function of motor octane number was so rapid that the gasoline yield declined from 100% to 0% within an increase of only one whole motor octane unit. Thus, all the points shown in Figure 18 (which plots increased manufacturing costs versus motor octane number), maintained 100% yield of the base case. Again the rapid increase in manufacturing costs associated with higher motor octane numbers is readily apparent.

To test the sensitivity of our results to even greater increases in purchased crude prices, we made a set of runs at $10/Bbl delivered cost for imported sour crude oil. The new 1980 base case (under Scenario I) calculated an increase in composite gasoline cost from 25.26 CPG to 35.50. Figure 19 shows the increased gasoline costs versus motor octane number and displays a similar (though slightly steeper) slope than that shown in Figure 18.

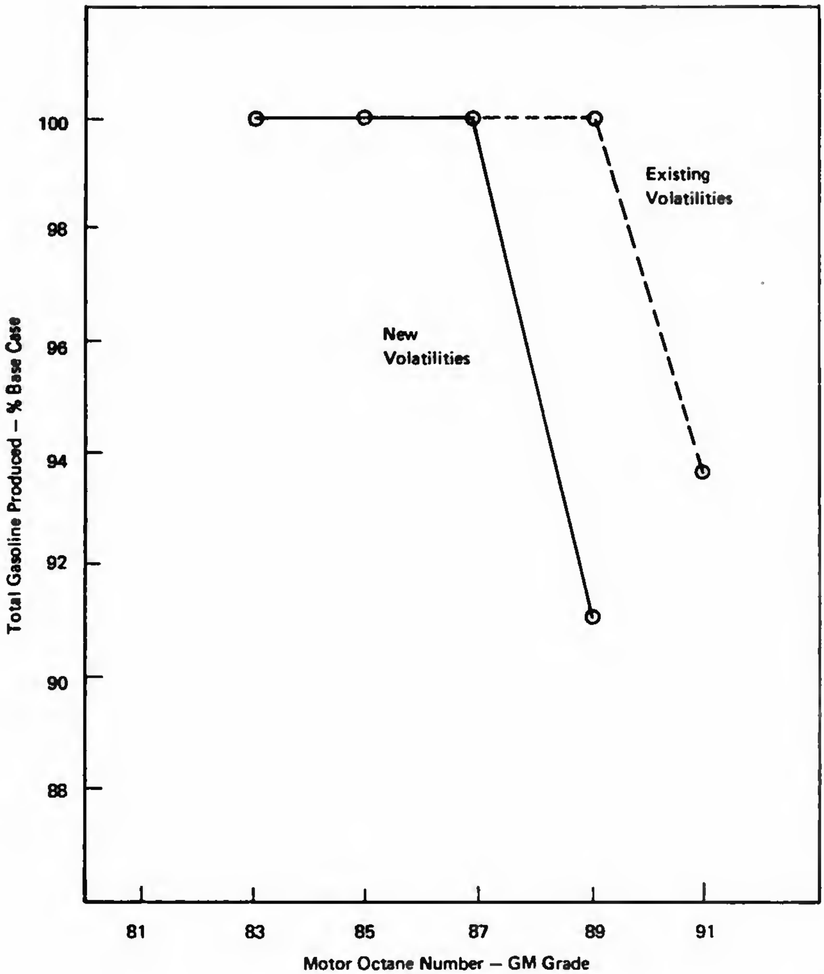


FIGURE 14 1980 OPERATIONS – TOTAL GASOLINE PRODUCTION VERSUS MOTOR OCTANE NUMBER – GM GRADE (Existing and New Volatilities – 50% GM)

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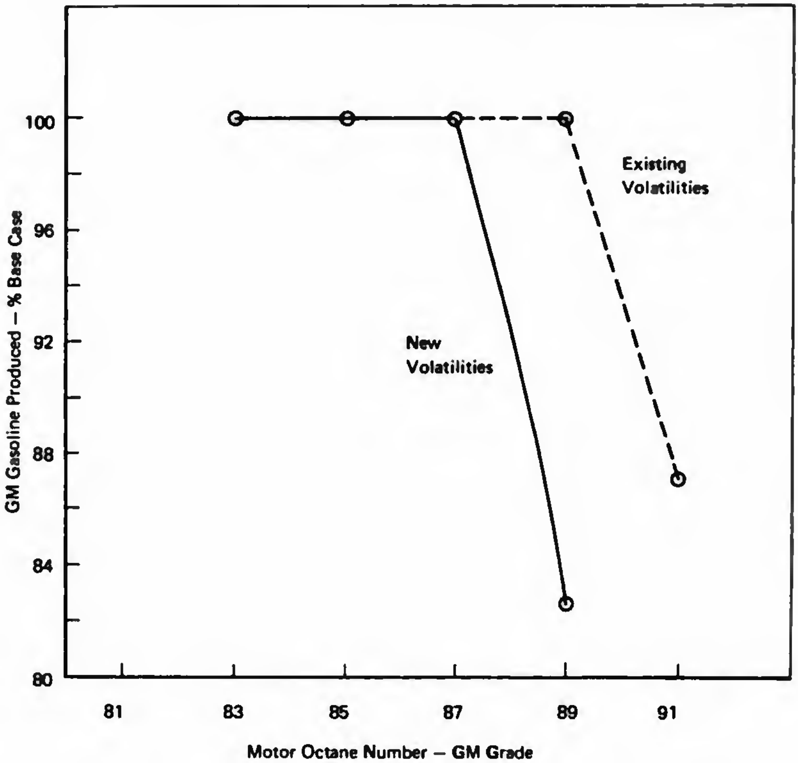

FIGURE 15 1980 OPERATIONS – GM GASOLINE PRODUCTION VERSUS MOTOR OCTANE NUMBER – GM GRADE
(Existing and New Volatilities – 50% GM)

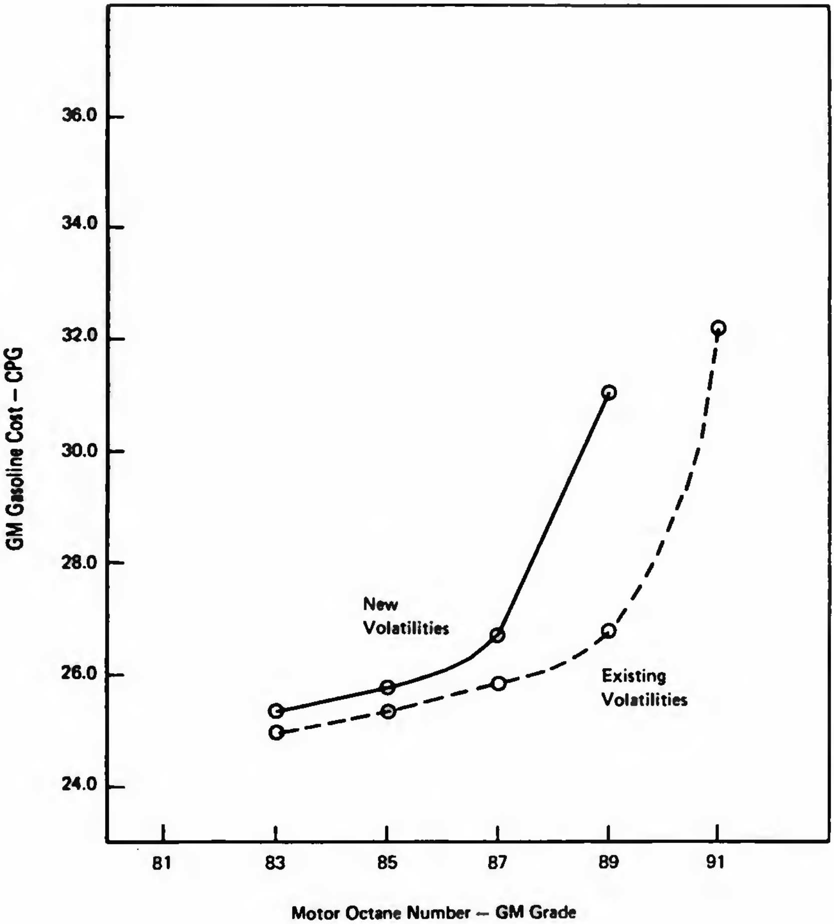

FIGURE 16 1980 OPERATIONS – GM GASOLINE COST VERSUS MOTOR OCTANE NUMBER – GM GRADE
(Existing and New Volatilities – GM Gasoline: 50%)

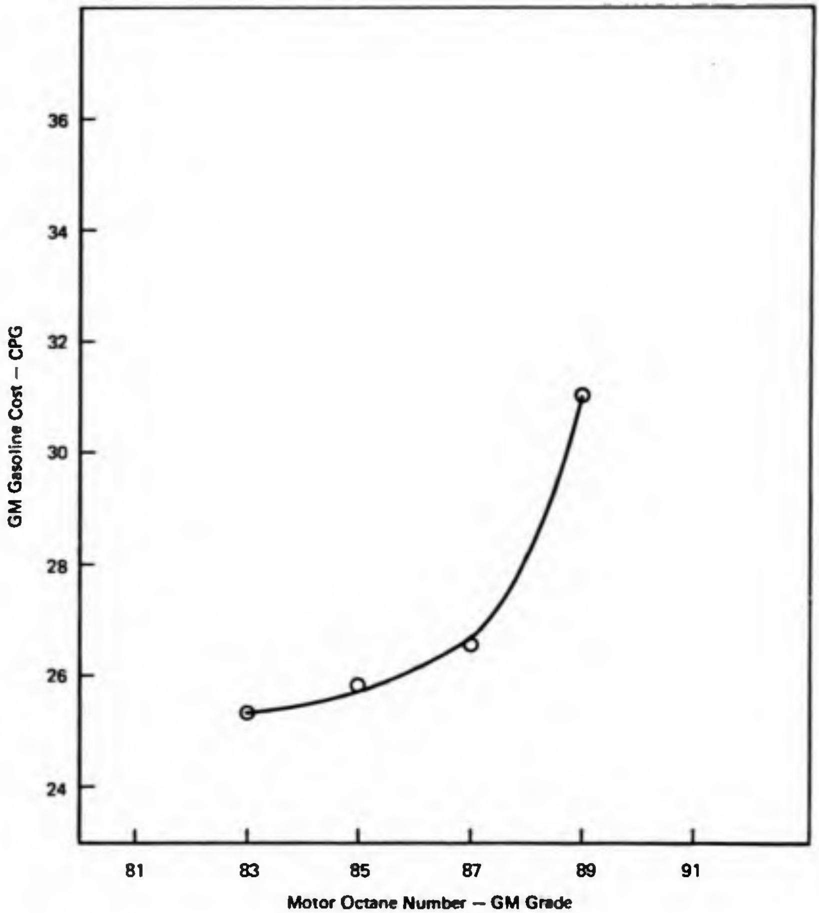

FIGURE 17 1980 OPERATIONS – GM GASOLINE COST VERSUS MOTOR OCTANE NUMBER – GM GRADE
(New Volatilities – GM Gasoline: 50%)
(Low % Premium in Conventional Grades)

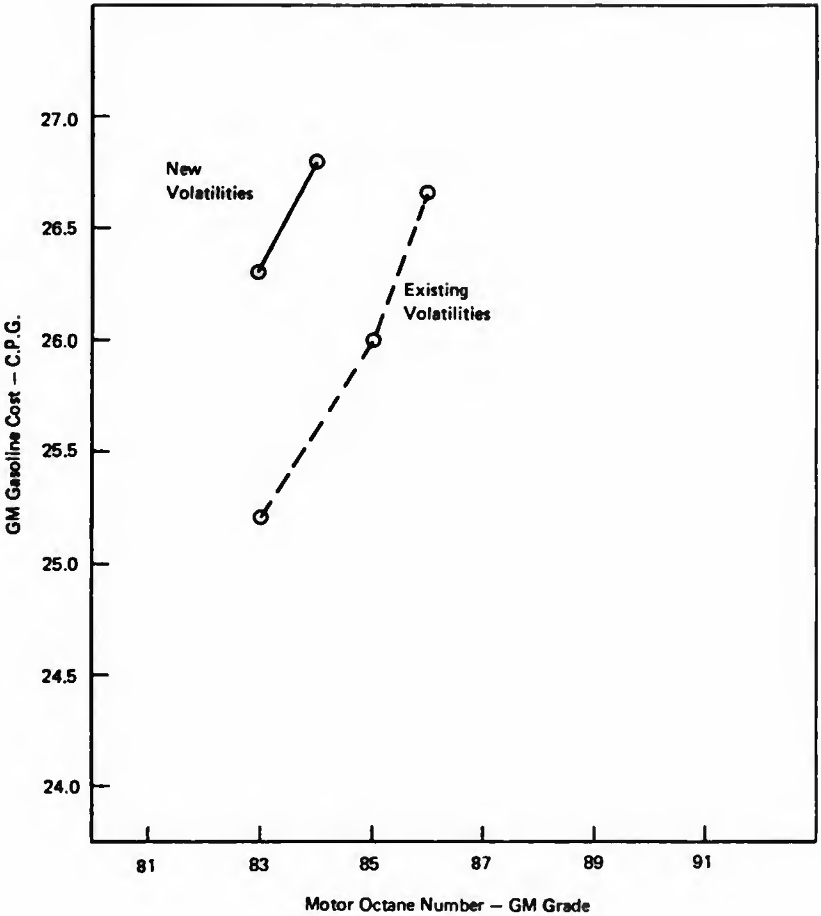

FIGURE 18 1980 OPERATIONS – GM GASOLINE COST VERSUS MOTOR OCTANE NUMBER – GM GRADE (Existing and New Volatilities – GM Gasoline: 100%)

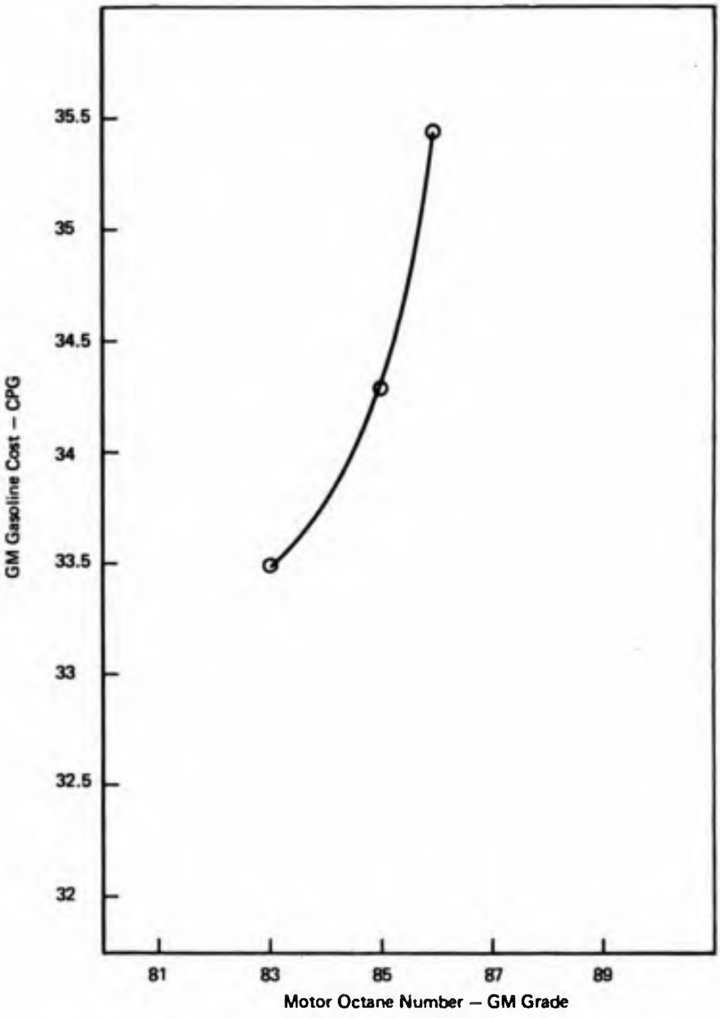

FIGURE 19 1980 OPERATIONS – GM GASOLINE COST VERSUS MOTOR OCTANE NUMBER – GM GRADE
(Existing Volatilities – GM Gasoline: 100%)
(Imported Sour Crude Price – $10/Bbl)

3. Capital Investments

The output from the optimized 1980 runs provided the refining capital investments required to achieve the increased product demands as well as associated product manufacturing specifications. These results are presented in Table XI. The base case for Scenario I (that is, continuing present motor gasoline grade structure) would require a refinery capital investment of $15 billion to achieve the increased product demand requirements by 1980. The alternative capital requirements shown in Table XI represent investments which would be required to achieve different volume levels and product specifications for unleaded gasoline production. The most severe case (i.e., making 100% GM gasoline at 94/86 RON/MON and existing volatilities) would require $19.3 billion rather than the $15 billion for the base case, or a net increase of $4.3 billion of capital investment. Thus, it appears that the huge refining capital investments that will be required by 1980 to expand supply of total products are not particularly sensitive to the percentage requirements for lead-free gasolines as long as the octane levels are moderate.

Although the capital requirements to produce 100% GM at 91/83 with new volatilities are less than with existing (16.2 versus 17.2), it must be remembered that the model optimizes the composite of raw material, operating and capital costs. Figure 12 illustrates that the resultant gasoline cost is more than 1 CPG higher for the new volatilities.

The 1980 base case for Scenario II (i.e., a significant change in engine design by 1975 such that essentially no premium gasoline and a large percentage of lead-free, low octane gasoline is required for 1980) results in essentially the same refinery capital expenditure for 1980 as the alternative scenario. The reduced manufacturing cost for this case (25.0 CPG versus 25.26) is due to reduced raw material requirements and operating expenses rather than a reduction in refining capital.

TABLE XI

NEW REFINING INVESTMENT REOUIRED
1973→1980 PERIOD
$ BILLION

BASE CASE (EXISTING GASOLINE SPECS) = $15.0 BILLION

GM Octane	Existing Volatilities		New Volatilities	
RON/MON	50% GM	100% GM	50% GM	100% GM
91/83	15.2	17.2	15.8	16.2
92/84	–	–		16.9
93/85	15.9	19.0	16.5	
94/86	–	19.3	–	
95/87	16.9		17.3	
97/89	18.2			

APPENDIX

ARTHUR D. LITTLE REFINERY SIMULATION MODEL

A. MODEL DESCRIPTION

Over the past several years, Arthur D. Little has developed large-scale computer models for simulating the major world refining centers. In such models a specified product demand pattern is met by a specified crude slate in an optimized refinery operation. An analysis of model outputs offers valuable insight into crude and refined product values with respect to the stated cost of a reference crude oil. In effect, the model continuously answers the questions: "What will it cost to produce an additional barrel of Product X?" and "What would an additional barrel of crude oil Y be worth relative to the reference crude oil and the other crude oils in the crude oil slate?"

A simplified refinery flow sheet shown in Figure 1 represents one of the models. This particular one is of the U.S. East Coast, but other models are similar. Each crude is allowed to select its own optimum processing scheme by the model simulating "blocked-out" operation. For example, the processing scheme chosen for Brega is most likely quite different from that selected for Tia Juana. The intermediate streams from each process unit can either be further processed or allocated to final product blending.

The main blocks of the refinery processing scheme can be broken down into: (a) naphtha, (b) gas oil, and (c) residual. The full-range (C5 – 400° F) untreated naphtha can be sold directly. Otherwise, the naphtha is split into several fractions for blending or further processing. The light (175-250) and heavy (250-400) naphthas can each be hydrotreated. Each hydrotreated naphtha can be routed to a catalytic reformer with the option of running at three different octane severities. The model chooses the optimum severity or it can bypass some naphtha into finished product blending.

The gas oil processing scheme is less complex than the naphtha. The full-range 400-650° F fraction can be split into a kerosene fraction and heavy gas-oil fraction, and each stream can be subsequently hydrotreated.

The residual fraction (atmospheric bottoms) can be directly blended to residual fuel oil or desulfurized before blending if from a sour crude origin. It can also be fed to a vacuum distillation unit; the vacuum overhead stream can then be hydrotreated for fuel-oil blending or fed to a catalytic cracker for conversion into lighter products. The model is allowed the option of choosing between two catalytic cracking conversion levels or two grades of vacuum gas oil feed. The propylene-butylenes from catalytic cracking can be fed to an alkylation unit or to a polymerization unit to make gasoline blending stocks. Vacuum bottoms can be

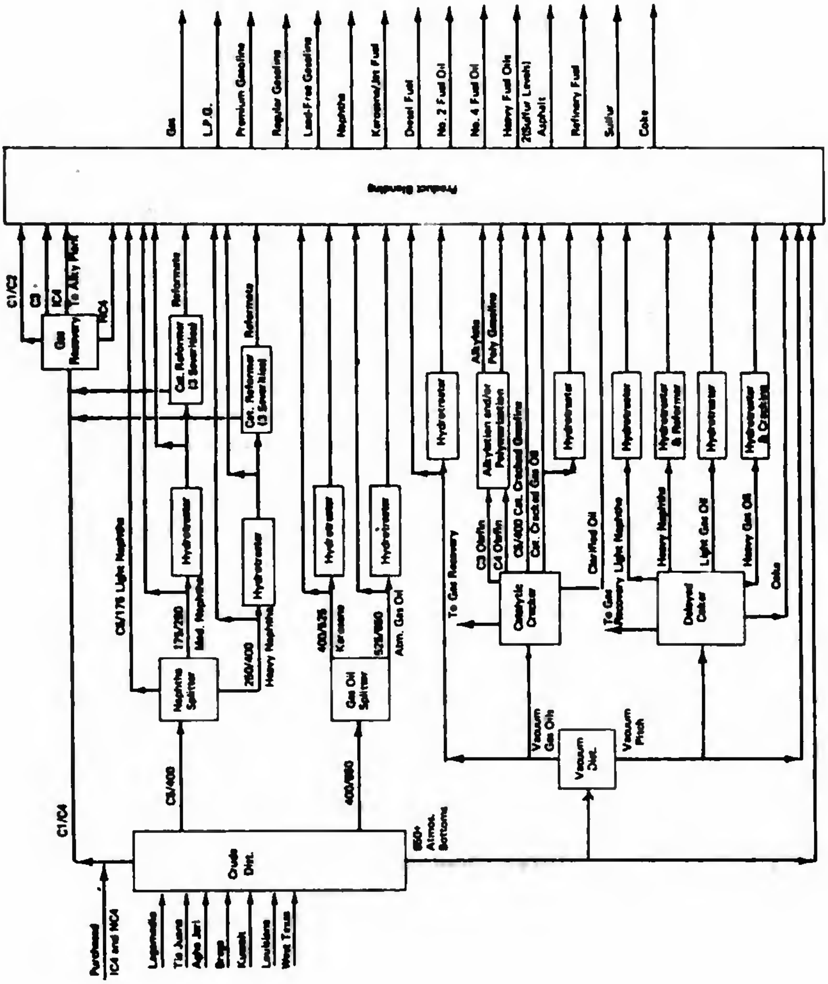

FIGURE 1 REFINERY FLOW SHEET
U.S. EAST COAST MODEL

routed to a coker to reduce the production of fuel oil and to produce some lighter products and coke. The coker naphtha can be hydrotreated and the heavy fraction reformed. The coker gas oil can also be hydrotreated and the heavy fraction cracked.

Additional processes in the model not shown on this refinery flow sheet include a hydrogen plant. (If the volume of hydrogen required for treating exceeds that supplied from catalytic reforming, then hydrogen must be manufactured either from refinery gas, naphtha and/or residual fractions). The refinery is usually required to generate its own steam and power, although these can be variable options. A sulfur plant is provided which converts hydrogen sulfide into elemental sulfur.

ADL has accumulated industry data for each processing unit for each crude oil. This includes yields and key properties of the products from that particular process, capital costs, and operating costs divided into the following seven categories: refinery fuel consumption, steam, water, electric power, catalysts and chemicals, operating labor, and maintenance. The capital and operating costs for each refinery process unit are based on modern units of the size consistent with 100 MB/D crude distillation capacity.

The costs of offsites for crude handling and product blending and storage is included and varies with crude distillation capacity. An internal refinery fuel balance is maintained (including fuel needed for steam generation, power generation, etc.) with a maximum sulfur content specification.

B. ECONOMIC BASIS

The data supplied to the model for the computer runs consist of:

1. Product demands and specifications;

2. Crude supply; and

3. Refinery processing options for each crude.

Product demands are usually fixed volumes which must be met. However, we occasionally allow a particular product volume to optimize at a specified netback, sometimes limiting minimum or maximum levels.

The basic assumption underlying our use of fixed product demands is that the total market for petroleum products in a refining center is relatively inelastic to changes in product prices. This is most true for products such as gasoline and jet fuel which have no competitive supply source. Heating oil and residual fuel have had inter-fuel competition from natural gas and coal in the past. One result of this is that residual fuel has been sold below its investment cost value. If we expect this condition to continue, we can remove the fixed volume restriction from residual fuel oil and allow it to seek its own optimum production level at an inter-fuel competitive price structure.

In a multi crude system, crude slate is usually specified as a fixed supply for all crudes except a reference crude which must be allowed to vary in order to meet a fixed product slate because it is not known in advance the exact volume of crude oil that will be required due to gains/losses from refinery processes and own fuel consumption. The volume of the reference crude consumed will vary somewhat from run to run. A delivered price is assigned to this reference crude, and all other crude and product values are determined relative to the reference crude oil price chosen.

For each refinery process in the model, the capital cost is supplied plus several categories of operating costs. The capital cost is converted to a daily cost basis via a capital recovery factor which is usually 20% per year. The capital charge provides for depreciation, income tax, property tax and insurance, and profit.

The linear programming code will optimize the refinery processing scheme at minimum cost to meet the required product demands and product specifications from the crude slate provided. It is assumed that complete interchange of intermediate streams from all crudes is possible. Also, for product specifications that are binding, the products are always blended exactly on specification and no quality is given away. Of course, in the real world, there are inefficiencies in processing and blending. Thus, the conversion and treating unit intakes determined by the model, represent bare minimums and in the actual refineries some excess capacity will be required.

The most useful outputs from the linear programming runs are the optimum refined process schemes chosen for each crude oil and the shadow prices for the refined products and crude oils. These shadow prices indicate the internal refinery values for each respective product and each crude oil and indicate the minimum long-term selling price that a particular product requires in order to justify capital expenditures for its manufacture or the maximum long-term purchase price for each crude oil. The product values (sometimes called investment cost values) are often used by major oil companies as transfer values when transferring products from refining to marketing divisions and also from refinery to petrochemical divisions.

The relative crude values simulate the internal crude oil values assigned by large, integrated oil companies which have the flexibility to reallocate crudes among various refineries to optimize its operations in a large geographic region.

In parametric evaluations, we systematically vary certain key uncertainties in our input data (such as product demand levels, specifications, operating costs, crude supply patterns, etc.) to test the flexibility of model outputs to these changes. A parametric evaluation consists of an alternate unique LP solution for each variation in input data. We can thus evaluate on a quantitative basis the extent to which a variation in a particular input forecast will affect the conclusions, in particular relative product prices and crude values.

It is important to emphasize that the crude and product values generated by the refinery simulation model are costs and not prices. Market constraints can and do limit the extent to which a refiner can recover the costs allocated to each product in the model. However, the model does show when additional costs are incurred in making more of a particular product. It indicates a lower market value for high-sulfur crude oils and a higher market value for low-sulfur crude oils as the demand for low-sulfur products increases. The crude oil values are not prices but replacement values; that is, the value at which a refiner would replace a barrel of the reference crude with the barrel of another crude oil. A high replacement value for a given crude oil means that the refiner can reduce refining costs by substituting this crude oil for a low replacement value crude oil.

DETAILED REFINING DATA

A. PROCESS DESCRIPTION

The model is intended to represent the total or individual regions of the U.S. refining industry on the basis of a typical 100 MB/CD refinery. The refinery was set up to run four crudes – a sweet and sour domestic crude and a sweet and sour foreign crude. The crudes are South Louisiana Mix (36.2 API), West Texas Sour (33.4 API), Nigerian Mix (29.5 API), and Saudi Arabian Light (34.5 API). Any combination of these crudes can be considered marginal or with fixed volumes.

Investment and operating cost data for each of the refinery processes in the model are intended to represent the costs of units whose size is consistent with a 100 MB/CD refinery. Both capital and investment costs can easily be escalated to represent inflation for future situations. A process-by-process description is given below, highlighting the major assumptions used in producing their representation.

B. ATMOSPHERIC DISTILLATION

Each crude is represented by a separate vector in order that the differences in the various stream qualities may be represented in downstream processes. Investments and maintenance costs for sour crudes are higher than for sweet crudes to reflect disadvantages of increased sulfur in the feedstock. In addition, the percentage of sour crudes run can be controlled by having a capacity restriction on these crudes.

C. VACUUM DISTILLATION

Once again, each crude has its own vacuum distillation vector to enable downstream processing to reflect the differences in stream yields and qualities.

D. CATALYTIC REFORMING

Naphtha from each crude has its own reforming vectors. Each crude specific naphtha is broken down into three feeds available for reforming – light, medium, and heavy. The light (160-200° F) and medium (200-340° F) feeds produce reformates which will meet the end point specifications of 365° F maximum on the special gasoline being studied for General Motors. The heavy feed, a 340° F to 375° F feed produces a reformate which does not meet the General Motors mogas E.P. spec. but is acceptable in conventional gasolines.

For light and medium feeds, four reforming severities are represented giving 90, 95, 100 and 103 Research Octane clear product. For heavy feed only 90, 95 and 100 severity are included since it is unlikely that this feed will be reformed at the highest severity for lead-free, low end point gasoline.

Feed capacity restrictions (of 1.03 and 1.06) are incorporated on operations at 100 and 103 severity to reflect the fact that existing reformers are designed for severities in the 90 to 95 clear octane range. When considering future processing requirements these restrictions are, of course, released.

Reforming of hydrocrackates from low severity operation is also represented at 90, 95, 100 and 103 severity. Reformate from these operations does not meet the 365° F end point specification because the feed hydrocrackate has too high an end point. In order to reduce the end point of the hydrocrackate, a special set of high severity hydrocracking operations is represented in the model and these are discussed later. The reformate from the reforming of this low end point hydrocrackate feed will then meet the 365° F end point specification.

Investment and operating costs for different reformer severity operations are increased with increasing severity to reflect the fact that higher investment would be required for a higher severity reformer and it would be more costly to operate.

E. CATALYTIC CRACKING

Catalytic cracking is represented by six options, namely a low and high severity operation on a sweet feed, a sour feed and a desulfurized sour feed. Only vacuum gas oil in the boiling range of 650° F to 1,050° F is considered as a feed since this is fairly typical of U.S. catalytic cracking operations. Lighter distillates can be hydrocracked.

Low severity operation is set at 65 volume percent conversion and high severity is set at 85%. Yields are based on Zeolitic type catalysts and are given in Table 1. A higher capacity utilization of 1.05 is placed on the high severity operation since most catalytic crackers are not designed to handle the same amount of fresh feed at high severity, even with a Zeolitic type catalyst.

Investments and operating costs are higher for the high severity operation and for the sour feed cases.

F. CATALYTIC CRACKED NAPHTHA SPLITTING

The catalytic cracked naphthas produced have end points around 430° F and, as such, are not suitable to meet a 365° F end point gasoline. In today's refining operations catalytic naphthas are normally split into a light and heavy naphtha. The light naphtha would, of course, meet the 365° F end point, but the heavy would not. Therefore, in addition to this normal splitting operation, we have added an alternative which produces a light catalytic naphtha, a medium catalytic naphtha, and a very light cycle oil. The medium catalytic naphtha will meet a 365° F end point and the light cycle oil produced can go to distillate blending.

TABLE 1

CAT CRACKING YIELDS USED IN U.S. REFINING MODEL

Feed	Sweet Vacuum Gas Oil Feed		Sour Vacuum Gas Oil Feed		Hydrotreated Sour Vacuum Gas Oil Feed	
Products LV%	Low Conversion	High Conversion	Low Conversion	High Conversion	Low Conversion	High Conversion
Fuel Gas (FOE)	0.025	0.048	0.025	0.048	0.018	0.033
C3 Olefins	0.052	0.070	0.052	0.070	0.056	0.075
Propane	0.013	0.030	0.013	0.030	0.020	0.043
C4 Olefins	0.076	0.108	0.076	0.108	0.081	0.116
Isobutane	0.046	0.090	0.048	0.090	0.070	0.128
Normal Butane	0.008	0.022	0.008	0.022	0.012	0.031
C5-430 Mogas	0.520	0.600	0.520	0.600	0.580	0.689
Light Cycle Oil	0.270	0.100	0.270	0.100	0.212	0.033
Heavy Cycle Oil	0.080	0.050	0.080	0.050	0.083	0.017
Total	1.090	1.118	1.090	1.118	1.112	1.145
H_2S (Lbs/Bbl)	0.382	0.382	2.995	2.995	0.382	0.382

G. HYDROCRACKING

Hydrocracking operations are represented by twelve vectors. Half of these represent existing operations and what we have termed low severity hydrocracking. The other half are the special high severity operations which produce low end point hydrocrackates to make reformate suitable for blending in 365° F end point gasoline. More hydrogen is consumed and feed capacity is reduced 5% for this operating mode.

Six types of feeds are allowed to the hydrocrackers, namely a sweet and sour feed of each of atmospheric heavy gas oil, vacuum gas oil, and cracked gas oil. All cracked gas oils are considered to have the same yields and these feeds include catalytic cycle oil, coker gas oil, and visbreaker gas oil. Table 2 lists both the low and high severity yields used in the study. Both investments and operating costs for sour operations and high severity operations are higher than for sweet low severity operations.

H. ISOMERIZATION

Isomerization of light naphthas (C5/160) has been included as an additional processing option which is likely to be required for the production of lead-free gasoline. Both once-through and recycle isomerization of each of the four crude specific light naphthas are included in the model.

I. OTHER GASOLINE PROCESSES

The other gasoline processes represented in the model are Polymerization and Alkylation.

J. OTHER CONVERSION PROCESSES

Other conversion processes represented are Coking and Visbreaking, which differentiate between sweet and sour feedstocks.

K. DESULFURIZATION

Desulfurization of naphthas, light and heavy gas oils, and vacuum gas oils from all crudes are included as processing options in the model. In addition, direct desulfurization of sour atmospheric bottoms (650° F+) to sulfur levels of 1.0 wt% and 0.5 wt% are included.

Cycle oils from sour catalytic cracking operations also have the option to be desulfurized. Naphthas from coking operations are required to be desulfurized before routing to product blending or reforming.

TABLE 2

HYDROCRACKING YIELDS USED IN U.S. REFINING MODEL

	Low Severity						High Severity					
	Heavy Atmos. Gas Oil Feed		Vacuum Gas Oil Feed		Cracked Stock Feed		Heavy Atmos. Gas Oil Feed		Vacuum Gas Oil Feed		Cracked Stock Feed	
Product Streams	Sweet	Sour	Sweet	Sour	Sweet	Sour	Sweet	Sour	Sweet	Sour	Sweet	Sour
H_2S (Lbs/Bbl)	.285	3.62	1.033	8.09	1.896	10.00	.285	3.62	1.033	8.09	1.896	10.00
H_2 (MSCF/Bbl Required)	1.900	1.950	2.050	2.100	3.100	3.150	2.090	2.146	2.255	2.310	3.410	3.466
C_2	.0040	.0040	.0057	.0057	.0050	.0050	.0078	.0078	.0111	.0111	.0105	.0106
C_3	.0540	.0540	.0768	.0768	.0670	.0670	.0800	.0800	.1123	.1123	.1055	.1055
IC_4	.1440	.1440	.1520	.1520	.1170	.1170	.1994	.1994	.2079	.2079	.1722	.1722
nC_4	.0600	.0600	.0630	.0630	.0520	.0520	.0798	.0798	.0826	.0828	.0733	.0733
Light Hydrocrackate	.3640	.3640	.3820	.3820	.3170	.3170	.4577	.4577	.4747	.4747	.4238	.4238
Heavy Hydrocrackate	.6600	.6600	.6920	.6920	.7800	.7800	.6129	.5129	.5378	.5378	.6062	.6062
Vol. % Yield	1.286	1.286	1.3715	1.3715	1.338	1.338	1.3374	1.3374	1.4264	1.4264	1.3915	1.3916

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Investment and operating costs on the sulfur manufacturing process include provision for a centralized H_2S gas scrubbing system which is necessary when producing elemental sulfur and is not included as part of each individual hydrotreating process.

L. GASOLINE BLENDING

The gasoline blending data was developed from other published studies such as *U.S. Motor Gasoline Economics – A.P.I. June 1, 1967* supplemented by our own in-house analysis and is presented in Table 3.

TABLE 3

MOGAS COMPONENT BLENDING QUALITIES
REFORMATES

Component	R.V.P.	RON Clear	RON 0.5CC	RON 3.0CC	MON Clear	MON 0.5CC	MON 3.0CC	Volatility % Distilled At °F 130	160	190	210	290	310	330
Reformate 90														
Lt. feed	10.8	90.5	93.7	97.8	80.1	64.8	90.0	4.0	12.2	71.5	93.1	100.0	100.0	100.0
Med. feed	5.3	90.5	93.7	97.8	80.1	84.8	90.0	0.5	2.6	10.3	17.4	93.7	92.5	97.9
Heavy feed	1.4	90.5	93.7	97.8	80.1	64.8	90.0	-1.0	-0.5	0.0	0.8	14.0	22.3	34.0
Reformate 95														
Lt. feed	11.0	95.3	97.2	100.2	92.1	87.4	91.6	4.8	13.5	77.0	94.5	100.0	100.0	100.0
Med. feed	5.5	95.3	97.2	100.2	92.1	67.4	91.6	1.6	3.9	11.3	19.5	94.7	93.2	99.0
Heavy feed	1.5	95.3	97.2	100.2	82.1	97.4	91.9	-1.0	-0.5	0.0	1.0	14.5	22.5	34.0
Reformate 100														
Lt. feed	11.3	99.8	101.8	102.9	96.0	90.5	93.5	9.5	17.0	93.0	96.2	100.2	100.2	100.2
Med. feed	5.8	99.8	101.8	102.9	96.0	90.5	93.5	4.4	6.5	13.6	20.2	65.7	93.9	96.2
Heavy feed	1.8	99.8	101.8	102.9	99.0	90.5	93.5	1.0	2.4	2.5	2.7	15.5	23.0	34.2
Reformate 103														
Lt. feed	11.6	102.5	104.1	104.7	88.0	92.9	95.0	11.2	19.7	69.5	97.9	100.3	100.3	100.3
Med. feed	6.1	102.5	104.1	104.7	99.0	92.9	95.0	6.5	6.7	15.3	21.8	69.5	94.4	100.1
Heavy feed	2.1	102.5	104.1	104.7	88.0	92.9	95.0	2.5	4.5	4.5	4.5	17.0	24.0	34.3
Lt. refm. Ex 95 Md feed	11.5	94.4	98.7	92.3	71.9	79.0	95.8	9.5	20.0	66.5	97.0	100.0	100.0	100.0
Hy. refm. Ex 95 Md feed	1.5	102.6	104.2	105.5	99.9	93.0	96.6	-6.0	-2.8	0.0	0.0	32.0	66.5	91.0
Lt. refm. Ex 100 Md feed	11.9	90.5	93.0	95.1	77.0	93.3	89.0	10.0	23.0	68.0	89.0	100.0	100.0	100.0
Hy. refm. Ex 100 Md feed	1.7	106.0	107.7	108.1	92.0	95.3	99.5	-4.0	-1.5	0.0	0.0	34.0	67.0	93.0
Reformate 90														
Heavy hydr. feed	9.4	90.5	93.7	97.8	80.1	94.8	90.0	1.2	4.2	14.0	22.0	60.9	70.2	99.9
Mod. heavy hydr. feed	7.4	90.5	93.7	97.8	80.1	94.8	90.0	1.5	4.8	15.2	25.3	93.8	92.4	97.6
Reformate 95														
Heavy hydr. feed	9.7	95.3	97.2	100.2	82.1	97.4	91.9	3.3	6.9	16.3	24.5	61.2	70.5	89.0
Mod. heavy hydr. feed	7.7	95.3	97.2	100.2	62.1	97.4	91.6	3.7	7.3	19.1	30.0	94.2	92.7	97.5
Reformate 100														
Heavy hydr. feed	7.0	99.8	101.8	102.9	99.0	90.5	93.5	9.4	9.7	19.8	26.2	62.0	71.0	89.1
Mod. heavy hydr. feed	9.0	99.8	101.8	102.9	96.0	90.5	93.5	7.1	10.8	20.8	31.5	85.2	93.1	97.7
Reformate 103														
Heavy hydr. feed	7.3	102.5	104.1	104.7	88.0	92.9	95.0	9.6	11.5	21.2	27.9	62.5	71.0	89.3
Mod. heavy hydr. feed	8.3	102.5	104.1	104.7	88.0	92.9	95.0	10.0	14.0	23.0	33.0	99.0	93.5	97.9
Reformate 95														
Coker Naphtha feed	4.5	95.3	97.2	100.2	92.1	87.4	91.6	1.9	3.6	11.3	19.5	64.5	80.0	94.0
Reformate 100														
Coker Naphtha feed	4.8	99.8	101.8	102.9	99.0	90.5	93.5	4.4	6.5	13.9	20.2	65.5	80.4	94.2

TABLE 3 (Continued)

STRAIGHT RUN GASOLINES AND ISOMERIZED GASOLINES

Crude – Component	R.V.P.	RON Clear	RON 0.5CC	RON 3.0CC	MON Clear	MON 0.5CC	MON 3.0CC	Volatility % Distilled At °F 130	150	190	210	290	310	330	SG
Arabian Light															
C_5/375 (27.3 LV%)	3.8	39.8	46.7	65.0	39.8	48.0	63.5	0.0	3.0	18.0	26.5	72.5	81.5	90.0	.736
C_5/160 (4.9 LV%)	11.0	66.0	72.3	65.6	64.5	69.6	82.2	66.2	91.3	105.0	100.0	100.0	100.0	100.0	.657
160/200 (3.3 LV%)	6.0	52.3	57.4	73.7	51.8	56.5	73.5	0.0	0.0	80.0	105.0	100.0	100.0	100.0	.687
C_5/200 (8.2 LV%)	9.0	60.5	66.3	80.6	59.4	64.3	78.7	30.0	53.5	95.0	105.0	100.0	100.0	100.0	.669
Louisiana Mix															
C_5/375 (23.6 LV%)	3.2	56.6	62.4	77.3	58.1	62.7	75.9	0.0	0.5	11.0	19.5	66.5	77.0	67.5	.761
C_5/160 (3.7 LV%)	11.0	73.5	80.2	91.1	77.0	80.7	88.7	66.2	91.3	105.0	100.0	100.0	100.0	100.0	.668
160/200 (2.7 LV%)	4.1	72.8	77.1	68.5	74.4	77.4	87.3	0.0	0.0	70.0	105.0	100.0	100.0	100.0	.727
C_5/200 (6.4 LV%)	8.1	73.2	78.9	90.0	75.9	79.3	86.1	20.0	41.0	67.0	95.0	100.0	100.0	100.0	.693
West Texas Sour															
C_5/375 (28.3 LV%)	3.7	58.8	62.2	72.9	58.3	59.2	69.7	0.0	1.1	13.5	26.5	72.5	62.5	91.5	.745
C_5/160 (5.7 LV%)	11.5	71.3	77.3	89.1	75.0	77.8	84.8	66.2	91.3	105.0	100.0	100.0	100.0	100.0	.664
160/200 (3.8 LV%)	5.0	70.1	74.3	85.6	72.3	74.1	62.6	0.0	0.0	75.0	105.0	100.0	100.0	100.0	.732
C_5/200 (9.5 LV%)	6.9	70.8	76.1	87.7	73.9	76.3	83.9	28.0	51.0	90.0	98.0	100.0	100.0	100.0	.691
Nigerian Forcados 29.5°															
C_5/375 (20.6 LV%)	3.2	66.5	70.7	81.3	64.0	67.7	78.1	0.0	0.5	9.0	17.5	63.0	74.0	85.0	.761
C_5/160 (2.7 LV%)	11.0	82.0	87.1	95.5	83.0	87.1	92.0	66.2	91.3	105.0	100.0	100.0	100.0	100.0	.670
160/200 (3.4 LV%)	4.1	78.8	83.9	93.1	79.8	63.9	90.8	0.0	0.0	70.0	105.0	100.0	100.0	100.0	.727
C_5/200 (6.1 LV%)	8.1	60.2	85.3	94.2	81.2	85.3	91.2	20.0	41.0	87.0	95.0	100.0	100.0	100.0	.702
Natural Gasoline															
C_5/160	12.0	79.5	84.6	94.1	78.3	81.9	90.0	66.2	91.3	105.0	100.0	100.0	100.0	100.0	.643
C_5/200	10.8	78.9	84.0	93.5	77.8	81.7	89.9	30.0	53.5	85.0	105.0	100.0	100.0	100.0	.672
Arabian Light															
Once Through Isomate	11.5	78.0	86.0	91.5	75.5	82.2	87.1	75.0	98.0	105.0	100.0	100.0	100.0	100.0	.650
Recycle Isomate	12.5	87.0	93.0	97.0	84.5	91.6	96.0	85.0	105.0	105.0	100.0	100.0	100.0	100.0	.640
Louisiana Mix															
Once Through Isomate	12.5	82.1	90.5	96.0	62.1	66.4	93.0	75.0	96.0	105.0	100.0	100.0	100.0	100.0	.650
Recycle Isomate	13.5	90.0	98.3	99.9	86.0	94.2	99.0	85.0	105.0	105.0	100.0	100.0	100.0	100.0	.640
West Texas Sour															
Once Through Isomate	12.5	81.0	89.5	95.0	81.0	86.7	91.0	75.0	98.0	105.0	100.0	100.0	100.0	100.0	.650
Recycle Isomate	13.5	89.0	96.1	98.9	86.5	93.2	98.0	85.0	105.0	105.0	100.0	100.0	100.0	100.0	.640
Nigerian Forcados															
Once Through Isomate	13.5	87.0	96.3	100.0	87.0	93.0	97.0	75.0	98.0	105.0	100.0	100.0	100.0	100.0	.650
Recycle Isomate	14.5	92.5	98.3	102.2	88.0	96.3	101.1	85.0	105.0	105.0	100.0	100.0	100.0	100.0	.640

TABLE 3 (Continued)

OTHERS

Components	R.V.P.	RON Clear	RON 0.5CC	RON 3.0CC	MON Clear	MON 0.5CC	MON 3.0CC	Volatility % Distilled At °F 130	150	190	210	290	310	330
Isobutane	71.0	100.5	104.4	109.0	95.8	101.3	108.3	115.0	115.0	110.0	110.0	100.0	100.0	100.0
N. Butane	65.0	95.0	97.9	103.2	98.9	99.2	101.0	115.0	115.0	110.0	110.0	100.0	100.0	100.0
C_3 Alkylate	6.8	91.5	98.5	101.9	87.0	93.5	101.1	5.8	15.0	37.0	53.2	97.5	86.8	100.0
C_4 Alkylate	3.5	88.5	99.7	106.9	91.0	96.2	105.1	0.2	1.5	9.3	29.3	87.7	89.0	100.0
Light Hydrocrackate	13.1	85.8	90.8	97.3	82.4	88.9	98.1	75.0	92.0	100.0	100.0	100.0	100.0	100.0
Poly Gasoline	1.0	100.2	99.5	101.5	83.2	85.3	85.5	-18.0	-13.0	-5.0	-2.0	13.5	42.0	78.0
Iso Pentane	20.4	83.1	97.5	102.7	87.5	94.5	101.9	110.0	110.0	100.0	100.0	100.0	100.0	100.0
65% Conversion Cat. Naphthas														
C_5-430 Cat. Naphtha	8.2	93.9	96.1	98.8	77.7	81.4	84.3	5.5	17.0	37.8	48.7	73.2	79.5	86.0
C_5-350 Cat. Naphtha	7.8	98.0	87.9	100.2	78.3	82.2	84.9	12.5	27.5	50.0	61.0	81.3	95.0	87.5
250-450 Cat. Naphtha	0.5	85.5	89.0	93.2	75.2	78.3	82.0	-36.0	-28.0	-15.0	-10.0	10.0	16.5	25.0
C_5-250 Cat. Naphtha	11.0	98.4	89.8	102.0	81.7	84.8	87.8	27.5	52.0	83.0	90.4	100.0	100.0	100.0
250-413 Cat. Naphtha	0.5	90.0	92.9	88.3	78.2	81.1	84.5	-25.0	-20.0	-10.0	-8.0	50.0	62.5	78.0
250-365 Cat. Naphtha	1.0	82.0	94.8	97.9	79.7	82.5	86.0	-20.0	-15.0	-5.0	-3.0	60.0	78.0	97.0
85% Conversion Cat. Naphthas														
C_5/430	6.2	95.3	88.1	100.2	80.1	83.4	85.7	5.5	17.0	37.8	48.7	73.2	78.5	86.0
C_5/350	7.6	98.4	99.9	101.8	80.7	84.2	86.3	12.5	27.5	50.0	81.0	91.3	95.0	87.5
250-450	0.5	87.9	90.9	94.5	77.7	80.2	83.3	-36.0	-28.0	-15.0	-10.0	10.0	18.5	25.0
C_5/250	11.0	100.9	101.6	103.4	84.1	85.8	89.2	27.5	52.0	83.0	90.4	100.0	100.0	100.0
250-413	0.8	80.5	93.4	96.8	78.7	81.8	85.0	-25.0	-20.0	-10.0	-8.0	50.0	62.5	79.0
250-365	1.0	92.5	95.1	88.2	80.2	83.1	88.5	-20.0	-15.0	-5.0	-3.0	60.0	78.0	97.0
Visbreaker Naphtha	3.3	62.3	86.0	71.4	58.8	59.1	62.8	0.0	3.0	11.0	18.0	78.5	87.0	95.0
Light Coker Naphtha	18.2	78.0	83.3	90.7	71.2	74.8	79.9	42.0	62.5	93.5	99.0	100.0	100.0	100.0
Medium Coker Naphtha	1.2	55.0	60.1	67.7	52.2	56.9	63.9	-15.0	-10.0	0.0	1.0	64.5	80.0	94.0

Mr. SATTERFIELD. I appreciate that, Mr. Chairman.

Now, let me ask you this question. We have gone down to 91 octane gasoline. Does this not mean a decrease in compression ratios?

I believe you testified to this.

Mr. COLE. Yes; it does. We selected the 91 octane level, or the compression ratio to be compatible with it, because we were looking at the compromise between emissions, thermal efficiency of the engine, and of course economy. That is, thermal efficiency and the economy go hand in hand, and the emission output, as you raise compression ratios, tends to increase—particularly on hydrocarbons and oxides of nitrogen.

Mr. SATTERFIELD. You were also looking at the catalytic device, were you not?

Mr. COLE. We were looking at the catalytic device at that time as the one means of meeting the 1975 requirements proposed, and these proposed requirements were about one-fourth as stringent as we actually received. The original 1975 goal was shown to us at the White House on the 20th of November, 1969, which was just about one-fourth as stringent as actually the 1970 amendment to the Clean Air Act required.

Mr. SATTERFIELD. Let me ask you this question. On page 5 you say, on previous occasions we have urged the continuation of emission standard levels no more stringent than the 1975 interim California standards.

Since you say no more stringent, would not 1974 be acceptable to you?

Mr. COLE. As far as we are concerned, if that is the judgment of Congress, considering the effect on the economy and the effect on ambient air quality then the 1974 standards would be satisfactory to General Motors. But on the other hand, we feel because of the energy concern that if we know how to save 13 percent of our fuel by going to more stringent standards, that we have a serious problem in our own judgment whether we should recommend the 1974 standards or go to the more stringent standards with the catalyst.

Mr. SATTERFIELD. When you say 13 percent, you are only talking about 13 percent of the gasoline that goes into the automobile tank, are you not?

Mr. COLE. This is correct.

Mr. SATTERFIELD. Now, what I am concerned about is how we conserve the overall volume available to the public in all of the variant grades, and it seems to me that you do not have a 13-percent gain there. We already have a loss, and there is a penalty according to testimony we had yesterday, to produce this nonleaded gasoline.

Mr. COLE. Well, the losses—you must describe them as not being just emission losses. We have been on a collision——

Mr. SATTERFIELD. I am talking about consumption of gasoline losses.

Mr. COLE. I am talking about the consumption of gasoline.

We have been on a collision course with some of the regulations coming out of the Department of Transportation that has increased the weight of our cars, and you cannot increase the weight of a car, such as with the heavier bumpers, and other factors, without increasing the fuel consumption. And you can use the rule of thumb, if you would like to, of about 1 mile per gallon for every 400 pounds, you increase the weight of the car. And our cars, roughly from 1970 to 1974, are approximately 500 pounds heavier.

Mr. SATTERFIELD. We have had testimony here that there has been as much as a 20-percent loss.

Mr. COLE. Well, that is a combination, sir.

Mr. SATTERFIELD. It looks like that comes from someplace other than weight.

Mr. COLE. Well, it is a combination. We have those delineated as to what compression ratio meant in the way of loss, how much the weight was, and we would be glad to submit that to the record, and we did submit that to the Senate subcommittee in this area.

Mr. SATTERFIELD. Mr. Chairman, I know my time is up. I would like to ask one question right there.

I would like to know what is the loss due to your compression ratio change?

Mr. COLE. Approximately 2 percent.

Mr. SATTERFIELD. Two percent?

Mr. COLE. Yes, sir, and that is overall.

Mr. SATTERFIELD. How much of a compression ratio reduction has there been in the last 3 years?

Mr. COLE. Well, in 1970 we had about 40 percent compression ratio engines, and we had about 60 percent of our cars designed to run on regular fuel. Those regular fuel cars were adjusted on a minimal basis, maybe four-tenths of a ratio, to bring them in line for the 91 requirement. The others were adjusted more severely from compression ratios of around 10 to 1 down to around 8½ to 1.

Mr. SATTERFIELD. Thank you, Mr. Chairman.

I have other questions. I know my time is up now, and I will catch it on the second go-round.

Mr. ROGERS. Certainly.

Mr. Nelsen.

Mr. NELSEN. You mentioned the added weight. Now, some of those requirements as to the weight of an automobile, are any of those because of requirements that have been exacted on the industry by Government regulation?

Mr. COLE. Yes. There are several requirements, Mr. Nelsen. One is the energy-absorbing bumpers at a 5-mile-per-hour barrier impact level, along with the addition of a pendulum requirement. We have this exactly, and I can add it into the record.

Mr. ROGERS. I think it would just be well to put this all in the record.

[The following information was received for the record:]

ADDITIONAL WEIGHT PER CAR BECAUSE OF MANDATED ENERGY-ABSORBING BUMPER SYSTEMS

Since 1971, substantial changes have been made to the front and rear bumper systems on General Motors passenger cars. These changes, which were necessary to meet the 5 mph front and rear barrier and pendulum impact tests of MVSS 215, have added $155 (cost to the customer with no profit to GM) to the cost of a typical full-size GM vehicle. They have also increased the weight of a bumper system, including related structure, by 151 pounds. Beginning in 1976, additional bumper weight (estimated on some cars to range between 4 and 20 pounds, depending upon make and model) will be required to meet front and rear corner pendulum impact tests at the 16-inch height.

Mr. COLE. And this is the chart I have delineating the fuel effects and losses from these various changes, and not all of these changes are emission changes, but I do have the emission changes delineated along with these other elements that went into the changes of the car from 1970 to 1975.

Mr. NELSEN. On the engine design, it is my understanding that your earlier engines had a larger piston, a shorter stroke to go to the smaller piston, and the longer stroke to take advantage of the power that is in the combustion chamber.

Is that about the direction you are going on the engine?

Mr. COLE. Well, earlier our designs were what we called an oversquare engine where we had larger bore than we had stroke, and this caused what we called a higher surface-to-volume ratio. In other words, the surface of the piston in the combustion chamber was higher with an oversquare engine than with an undersquare engine. In the case of the Vega, when we designed it, we knew about some of these requirements on emissions so we did change the surface-to-volume ratio. We increased the stroke and made the combustion chamber surface less and the piston had less, which does tend to reduce the inherent emissions that come from the engine.

Mr. NELSEN. I read something about a rotating valve.

How do you get that valve to operate that way? Is it by a hydraulic system?

Mr. COLE. Mr. Nelsen, I am not quite sure about the rotating valves that you are talking about, valve rotators. Well, those are mechanically rotated by an arrangement of kind of a ratched mechanism.

Mr. NELSEN. I see.

Mr. COLE. As the valve goes up and down, the load is taken off of the valve spring, and it inches around. But, really, this has not much to do with passenger car engines, but we use that method on heavy duty operations, particularly in heavy duty truck operations.

Mr. NELSEN. Now, on the leaded gasoline, will that be made available so that those of us who may be driving an automobile that requires leaded gasoline will be able to get that fuel?

Mr. COLE. Yes. We have made changes in our valve mechanism, and not all valves have valve rotators, and not all valves need valve rotators. We have gone to a hardened valve seat. We take the cast iron that the valve seat is on and the head, and through induction, hardening high frequency induction hardening, we harden that seat so it is much harder than it was prior to going to unleaded fuel. We have also treated the valve itself, the surface of the valve, with a nickel alloy, in some cases, and with aluminum alloys in other cases, so that we do not get this tendency to weld when we lose the lubrication qualities of the lead in the gasoline.

Mr. NELSEN. You see, I am trying to detect the possibility that my little V–6 Buick—I want to be able to get the gasoline that I need until I wear it out. It has 95,000 miles on it; it is a 1965 model, and I refuse to give it up.

Mr. COLE. You need a new one.

Mr. NELSEN. No more questions.

Mr. ROGERS. Mr. Preyer.

Mr. PREYER. Thank you, Mr. Chairman.

They say statistics do not always lie, but they seldom voluntarily tell the truth. Some of these statistics here seem to fall in that area.

I wanted to ask Mr. Cole and Mr. Terry a few questions about their differences on the virtues of the catalytic converter.

First, I would like to ask Mr. Cole: If you use a catalytic converter on a car and use one tankful of leaded gas, does that ruin the converter, or does that just make it inoperative for that tankful?

Mr. COLE. It does not ruin the converter, and we can put that information into the record. We have run those tests where we have run a full tank of 3 grams per gallon of tetraethyl lead in the fuel. The converter will recover. But, on the other hand, if this is continued for an extensive period of time, then you do contaminate the converter with lead.

Now, I have to say this: That I believe—and I do not know enough about our competitive systems—but our system has been designed to tolerate a certain amount of lead from time to time from inadvertent filling was gasoline that does have lead in it. And we will submit that data to the committee so you can examine it.

Mr. ROGERS. Without objection, it will be made a part of the record.

[The following information was received for the record:]

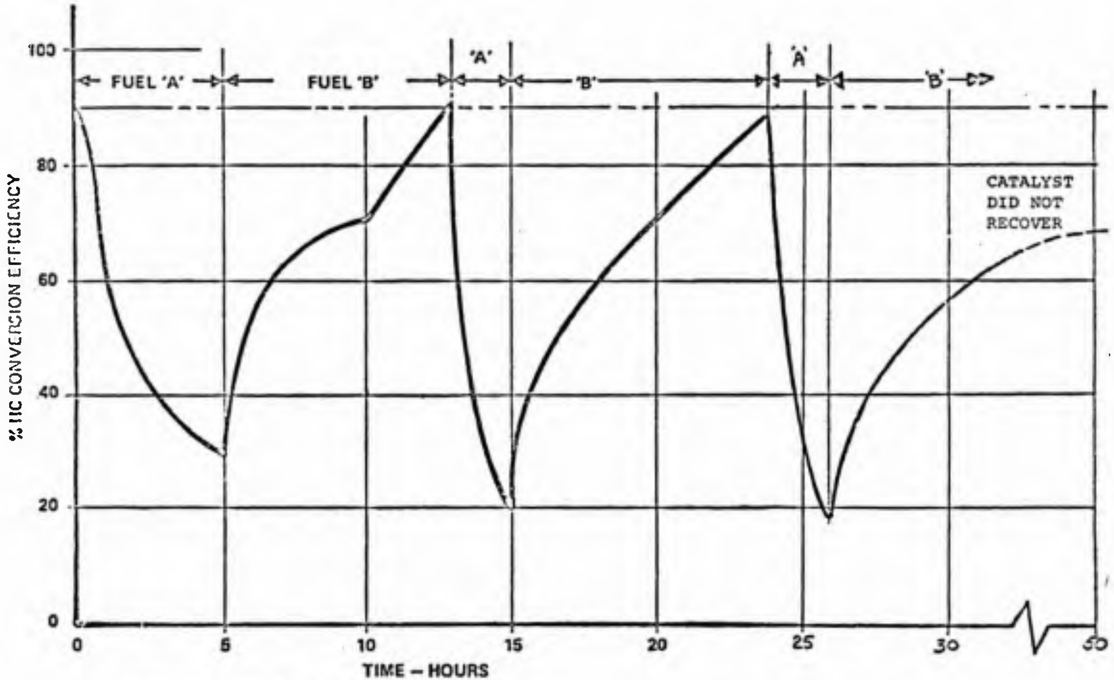
RECOVERY OF CATALYST AFTER POISONINO WITH LEADED GAS

General Motors test data indicates that the GM pellet catalyst planned for use on most, if not all, 1975 model cars to meet the 1975 interim standards will recover from up to 2 tanks of leaded fuel before the catalyst fails to fully recover. See Figure 2.

However, as noted in Figure 2, even though the catalyst does not fully recover when the third tank full of leaded gas is used, the catalyst does partially regain its capacity. The point at which the catalyst is completely destroyed is not shown by our data.

SUCCESSIVE COATING OF CATALYST

(LEADED FUEL, UNLEADED FUEL, LEADED — — — — —)



FUEL A INDOLENE 30 (3 gm/gal. lead)

FUEL B INDOLENE CLEAR

GM HAS INDICATED THAT –
"UP TO 2 TANK FULLS OF LEADED GAS"
WOULD NOT CAUSE PERMANENT DAMAGE.

11/26/73

Mr. PREYER. Does that depend on the type of catalyst that is used, as to whether it is a pellet-type or—what is the other?

Mr. COLE. Monolith.

Mr. PREYER. Monolith type. Does that make a difference?

Mr. COLE. Yes; there is a distinct difference, and these happen to be the pellets we are using. This is a gamma aluminum, and this is an aluminum bead. This bead is porous, so if you would spread the surface out, this would represent approximately 100 square feet of surface area in this bead, in this small bead.

And one thing that happens when lead does tend to deposit on the surface, as time goes on, is that this lead migrates into the center of the bead until it is completely filled with lead sulfates. And this is one advantage, we think, of our system with the porous-type bead; it does have that capacity, and it does the same thing for sulfur.

Mr. PREYER. Is there any sort of ballpark estimate of how many tankfuls of leaded gasoline you have to use before you do poison the catalyst? Has Chrysler——

Mr. COLE. Yes; we have that information, and we will submit it, and we will also show you the degradation of a catalyst with a certain level of lead in the fuel on a continuous basis, varying from, say, a tenth of a gram to three grams. There has been a lot of concern in the refining industry as to the upgrading of the fuel octane numbers if a small amount of lead could be used. But you must be down in the area of about 0.03 grams average epr gallon to insure a catalyst to run about 50,000 miles without replacing it.

Mr. PREYER. Well, that was the next question I wanted to ask you.

Mr. MISCH. Mr. Preyer, could I suggest one thing?

I would like also to submit for the record similar data with regard to monolithic catalyst that we are using to show the deterioration at varying levels of lead, so that they are both in the same record and can be compared.

Mr. ROGERS. Yes; that would be helpful.

Mr. MISCH. Our own experience indicates there is not that much difference between monolithic and pelleted catalysts.

Mr. ROGERS. What about Chrysler? You are using what type?

Mr. TERRY. We are using monolithic. We will be happy to submit our data for the record. [See p. 265.]

Mr. ROGERS. Thank you.

Mr. SATTERFIELD. Since we have a panel, since we have asked for information from some of the panelists, could we not just make the record open to each of them, if they want to submit information on that point?

Mr. ROGERS. I think that would be helpful.

[Testimony resumes on p. 296.]

[The following information was received from Ford Motor Co. for the record:]

THE EFFECT OF LEAD ON MONOLITHIC CATALYST ACTIVITY

To determine the sensitivity of our 1975 catalysts to lead in the fuel, Ford ran a series of laboratory experiments in which catalysts were operated with fuel having different amounts of lead. The results of these experiments are shown on the attached two curve sheets. These curves show the drop-off in catalyst efficiency with increased mileage when operated on fuel containing four different levels of lead. The specific lead levels were a laboratory "sterile" test fuel containing less than .003 grams per gallon of lead, .03 grams per gallon (certification lead level), .05 grams per gallon (maximum legal limit), and .5 grams per gallon (normal limit for low lead gasoline).

As shown from the attached curves, a significant drop in catalyst efficiency was observed for hydrocarbon removal as the lead level was increased. A slight but discernable difference was also noted in CO removal, but less than for hydrocarbons. This sensitivity of catalysts to lead is the basis for our requirement that they run only on lead-free fuel, that is, fuel with very low lead content. Any decrease in catalyst efficiency, of course, increases the tailpipe emissions of the vehicle. For example, hydrocarbon emissions would double if catalyst efficiency dropped from 80% to 60%.

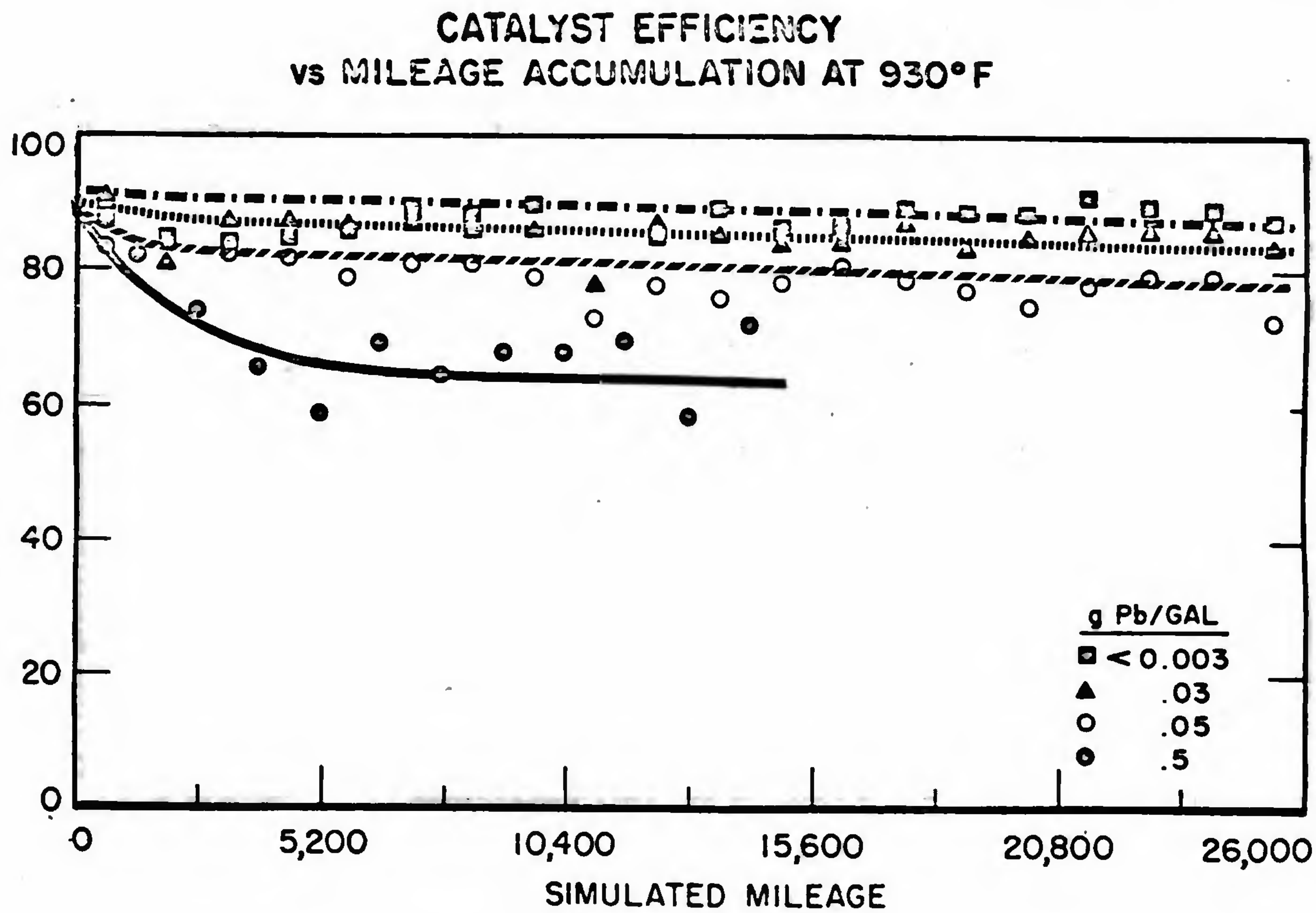
A certain amount of recovery of catalyst efficiency would normally be expected after a catalyst had been exposed to a limited amount of leaded or low-lead fuel, however, some permanent degradation is inevitable.

Ford has a fleet of 450 catalyst cars operating in the State of California to provide information on catalyst usage under a wide variety of customer-type operating conditions. Besides the catalyst information we are acquiring, we are also finding out the difficulty of operating vehicles on unleaded gasoline.

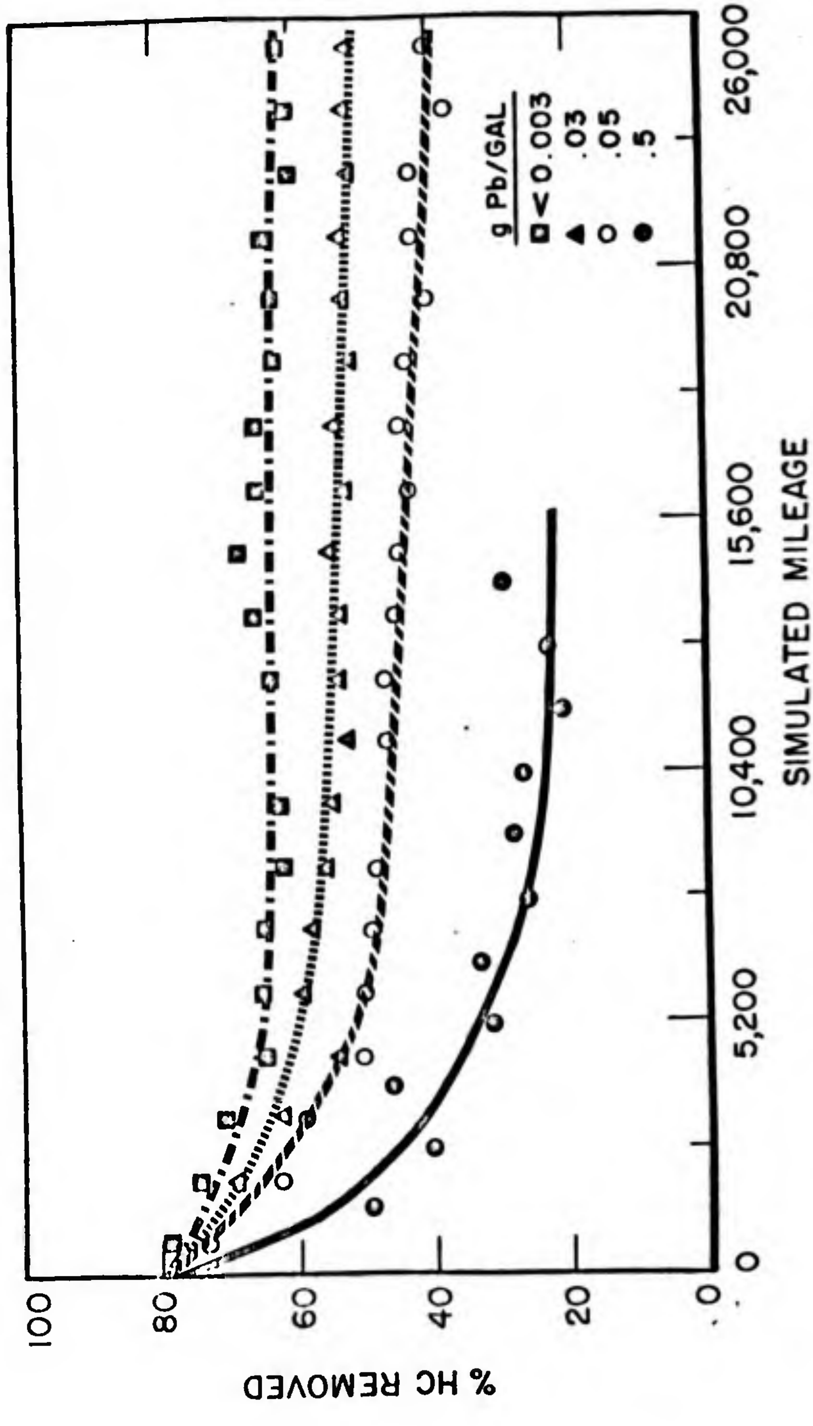
Recognizing the potential for such a problem, we went to the trouble of personally instructing each person that was assigned one of these fleet cars. Also, a very prominent sign saying that only unleaded fuel is to be used is attached to the exterior of the car close to the filler neck. We took these precautions recognizing that some difficulty might be experienced in finding unleaded gasoline, and the fact that these cars were not equipped with the small diameter filler neck which will be used on 1975 models. (Gasoline stations are not yet equipped with the special filler nozzle that will be nsed for dispensing unleaded gasoline next year.)

To date we have experienced 50 *known* cases of mis-fueling with leaded or low lead fuel on this California fleet test. This works out to an average of about one mis-fueling in every 240 fillings. We would hope that this would be drastically reduced next year on 1975 model cars with the use of the prescribed special filler necks and filler nozzles, nevertheless, these results are indicative of the fact that some mis-fueling is almost certain to occur.

We expect to have more data in future from this fleet test which will better define the effect of lead on catalyst efficiency in customer type operation.


CATALYST EFFICIENCY
vs MILEAGE ACCUMULATION AT 930°F
100
80
60
40
20
0
0
5,200
10,400
15,600
20,800
26,000
SIMULATED MILEAGE
g Pb/GAL
< 0.003
.03
.05
.5

CATALYST EFFICIENCY
vs MILEAGE ACCUMULATION AT 930°F



[The following information was received from Chrysler Corp. for the record:]

THE EFFECT OF LEAD IN GASOLINE ON THE EFFECTIVENESS OF PLATINUM-PALLADIUM CATALYST SUPPORTED ON CERAMIC HONEYCOMB

D. M. Teague, Chief Research Scientist; and E. J. Lesniak, Jr., Research Scientist, Research Office, Chrysler Corporation—December 14, 1973

Abstract

This report presents data on the effect of tetraethyl lead in gasoline on the activity of platinum-palladium catalyst. This type of catalyst, supported on ceramic honeycomb, is one of the production systems planned for control of emissions in 1975 Chrysler Corporation vehicles. It is clearly shown that the degrees of inactivation is directly related to the amount of lead present in the fuel used. While fully-leaded fuel is being burned in the vehicle there is a severe loss in the control of HC and CO emissions. A major part of this loss, but not all, can be recovered by the subsequent use of unleaded fuel. It has been found, however, that the inactivation of this type of catalyst is due to the ethyl chloride-bromide scavenger, normally included with tetraethyl lead.

It is also estimated that an increase in the average lead content permitted in 1975 unleaded fuel would produce a small increase in HC and CO emission throughout the life of the catalyst.

Discussion

Chrysler Research has made a study of the effect of tetraethyl lead in fuel on oxidative catalyst performance in reducing exhaust emissions. Most of the information has been obtained with platinum and/or palladium compositions on ceramic honeycomb substrate.

The most significant results are as follows:

Laboratory Data

Single-cylinder laboratory tests show that a palladium catalyst on honeycomb is rapidly degraded with leaded fuel (see Figures 1 and 2). After 5 hours of operation with fully-leaded fuel, it is estimated that the catalyst would no longer have made 1975 standards, either for CO or HC. The HC deterioration is more severe than that for CO in the 1000°F normal operating range of a vehicle.

These results are typical of both laboratory tube furnace and single-cylinder engine results.

Research Dynamometer Tests

Cylindrical (3.6" diameter X 3" long) oxidation catalysts (20% platinum - 80% palladium composition) were run for 100 hours as a durability test.* Four catalyst cylinders, with an effective bed volume of 100 in.^{3}, were run on the exhaust from a 360-CID engine. Figures 3 and 4 (black circles) show a small deterioration in CO and HC performance, when the engine was run on indolene clear (unleaded) fuel containing about 0.010 grams lead.

Similar catalyst units were then run on a fuel containing 0.30 grams of lead per gallon. This amount of lead, over 69 hours of testing, is equivalent to that contained in the fuel consumed by a typical car in 25,000 miles at 0.05 grams/gallon lead. The 0.05 grams/gallon is the maximum specified by EPA for 1975.

A much greater deterioration of CO oxidation is evident (Figure 3, open circles). We estimate that a car containing this catalyst would probably not meet the 1975 CO standard.

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*The endurance test schedule was similar to that developed by Dept. 7490, Engine Emissions and Performance. It is a simple cycle, alternating between a moderately heavy acceleration and idle engine conditions. A detailed description may be obtained from Dept. 9310, Chemical Research.

At 69 hours, the test was continued, again using indolene clear fuel to clean up the lead inactivation. It can be seen that the CO activity recovered about 75% back to what it would have been on indolene clear fuel.

Similar results were observed with respect to HC activity. Figure 4 shows a considerably greater loss in HC performance when leaded fuel was used. Furthermore, slightly less than half of the HC activity was recovered with lead-free fuel, compared with the same number of hours on indolene fuel.

These data indicate that the lead in a 1975 "unleaded" (0.05 grams/gallon) fuel will probably produce a significant deterioration of catalyst performance. They also suggest that a considerable recovery of performance after lead poisoning can be obtained by running with fuel containing little or no lead.

Filter for Removing Lead from the Fuel

A similar test was made on a special resin filter which apparently functions by decomposing the tetraethyl lead ester. We ran a test in which an experimental resin filter for lead was placed in the fuel line. The purpose was to remove the lead from the fuel before it was burned.

The same dynamometer test schedule was used, plus the same fuel containing about 0.3 grams (300 milligrams) per gallon of lead.

Table I shows the lead content of the fuel entering the filter. It was constant at about 300 milligrams per gallon. The fuel which passed through the filter contained a very small quantity of lead initially, but rose to about 200 milligrams after 57 hours.

Table I

Exchange Resin Lead Fuel Filter Efficiency

Leaded Fuel (hours)	Filter Inlet (mg/gal - lead)	Filter Outlet (mg/gal - lead)
8.6	302.8	4.3
28.2		23.0
48.8		45.0
56.8		198.5
61.6	301.0	198.5
71.5	302.8	227.1

Although the lead filter was carefully maintained at the recommended temperature of 90°f, the efficiency of the filter in removing lead was rapidly lost. It is not a satisfactory way to protect the catalyst from lead.

The effect on the catalytic oxidation of CO and HC was similar to the earlier test without the lead filter. Figure 5 shows this deterioration. The loss of CO and HC activity was similar to the previous test without the lead filter, though somewhat larger.

At 82 hours, the dynamometer run with the lead filter was returned to indolene clear fuel. As with the previous test, a substantial recovery in carbon monoxide performance and a small recovery in hydrocarbon performance was observed with the lead-free fuel.

These two tests led to the following observations:

1. Considerable deterioration of catalytic activity occurs with lead, even at a level of 0.3 grams per gallon lead.

2. Substantial recovery of carbon monoxide, and a small recovery of hydrocarbon performance occurs, if subsequently, essentially lead-free fuel is used.

3. The last observation suggests that most of the catalyst deterioration is a function of lead content in the fuel.

Car Tests

In 1971, Research Car 186, equipped with a 100% platinum-on-honeycomb catalyst met the equivalent of the original federal standards for 1975 (HC 0.41, CO 3.4, NOx 3.0 gm/mi). Car 186 results were HC 0.46, CO 4.7, NOx 3.0 gm/mi, using a 1972 test procedure. Table II shows that 52 gallons of such fuel caused emissions to rise well above the standards.

Table II

Car 186
Short Term Effect of Leaded Fuel
(2.3 ml. TEL per gal.)

Platinum-on-Honeycomb Oxidation Catalyst
1972 Procedure (HC .46, CO 4.7, NOx 3 g/mi)

Test No.	HC	CO	NOx	Gallons Test Fuel	Miles on Test Fuel
77	.18	4.4	2.02	5	94
78	.44	5.5	1.80	11	169
79	.08	3.4	2.53	16	262
80	.22	4.4	2.34	22	358
81	.62	11.1	2.23	52	753
82	.26	8.1	2.09	52	766
		Lead-Free Fuel			
83	.56	10.6	1.78	20	266
84	.31	7.4	2.31	40	544
85	.45	7.9	1.80	50	700

The total quantity of lead in this test is equivalent to using fuel containing .05 grams of lead per gallon for 35,000 miles. After 52 gallons of leaded fuel, the system no longer met the 1975 standards. It suggests that the lead content, alone, would cause this platinum catalyst to fail the 1975 standard before about 25,000 miles.

An additional 50 gallons of lead-free fuel showed some recovery, but did not bring the system back within levels then set for 1975.

In another test, five catalyst cars were being run at the Proving Grounds on the general endurance cycle. These were Cars 252, 339, 497, 668 (Engineering vehicles), and 433 (Research vehicle). All were running on indolene clear fuel containing only .008 to .012 grams/gallon of lead.

Unintentionally, a quantity of leaded fuel was added to the indolene clear tank. Varying quantities of this mixed fuel were used by the four cars mentioned above. Although the precise amount of lead contamination is not certain, data from the Fuel Laboratory indicate that this mixed fuel contained aaout 0.16 grams of lead of lead per gallon.

The cars showed an increase in emissions after the use of the low-lead fuel. After additional operation on essentially lead-free indolene, some recovery of emissions control was noted.

Averaging the results on the five cars shows the effect more simply. It compares emission levels on:

1. lead-free indolene, before use of low-lead fuel,
2. low-lead fuel (0.16 g/gal), and
3. Indolene again, showing recovery.

Table III

Effect of Low-Lead Fuel on Emissions
(Average of 5 cars)

	HC	CO	NOx
Test values on indolene, lead-free fuel (0.010 g/gal)	.42	3.21	1.67
After 447-1, 354 miles on low-lead fuel (0.16 g/gal)	.48	4.78	1.67
After 1,387 - 4,500 additional miles on indolene	.41	3.90	1.81

Although changes are not large, there appears to be some recovery when indolene (lead-free) fuel was used. CO remains about 20% higher than it was before the lead episode.

It should be pointed out, however, that the low-lead fuel inadvertently used, only averaged about 0.16 grams/gallon. This is but three times the proposed federal standard for 1975, and the number of miles on this fuel was only 447 - 1,354 miles. This is a very small exposure, compared with that expected in 1975, where the target is at least 25,000 miles, and the fuel may contain up to 0.05 grams/gallon lead.

EFFECT OF CATALYST COMPOSITION AND LEAD LEVEL ON CATALYST INACTIVATION DUE TO LEAD

In order to better understand the mechanism of precious metal inactivation of catalysts by lead, a more detailed study was made. To obtain more precise control of test conditions, this investigation was made on a multi-cylinder engine dynamometer.

Effect of Precious Metal Composition

In order to distinguish the effect of lead on individual precious metal components, experimental catalyst was made with either 100% platinum or 100% palladium as the active material.

Dynamometer Test Conditions

Lead exposure tests were run on a standard 360-CID engine with a 26-CID air pump and a 1.71:1 pulley ratio. The engine conditions during the durability cycle consisted of 45 seconds at 2400 rpm and 6 inches of manifold vacuum, followed by 15 seconds at idle. The catalyst activity test points were taken at 2,000 rpm and 6 inches of manifold vacuum. The inlet conditions to the catalyst during both the durability and the activity tests were:

1. 1 to 1½% CO,
2. 850°F, and
3. 5% O_2.

Catalyst Sample Composition

Experimental samples were made on extruded Corning substrate. Sample size was 3.6" diameter by 3" long, combined to make a useful bed volume of 100 in.^{3}. Either platinum or palladium was used as the catalyst, at a concentration of 0.2% by weight of the honeycomb support.

The catalyst units were run for 9 hours on unleaded fuel (indolene clear containing .010 grams of lead per gallon). A slight normal drop in activity due to factors other than lead poisoning occurred during this preliminary period.

The engine was then run on fuel containing 0.161 grams per gallon of tetraethyl lead for 112 hours. This is equivalent to the amount of lead which would be contained in the total fuel used in a typical automobile in 25,000 miles, burning fuel containing the 1975 maximum of .05 grams per gallon lead.

After 112 hours of running on the leaded fuel, the engine and catalyst were again run for another 10 hours with indolene clear unleaded fuel. This was intended to show the degree of recovery possible with unleaded fuel.

Figure 6 shows the results obtained. The solid lines indicate that there is a drop in CO removal from 97.7% to 92.5% when platinum is the catalyst. When palladium is the catalyst, the drop in CO conversion is from 91.8% to 85.0% conversion. This indicates a more severe poisoning of a palladium catalyst by lead in the fuel, than for platinum.

Similarly, a loss in HC conversion from 79.5% down to 71.2% occurs with a platinum catalyst. With a palladium catalyst, the HC loss is from 70% to 58% due to lead. This indicates that lead poisons a palladium catalyst much more severely than it does a platinum catalyst.

In a similar fashion, it can be seen that a platinum catalyst (solid lines) recovers a very considerable part of the poisoning loss when unleaded fuel is again used to operate the engine.

Palladium recovers only slightly in terms of CO activity, and not at all in terms of HC activity.

This result indicates that palladium is substantially, and almost irreversibly, poisoned in its catalytic activity when there is lead in the fuel. Platinum, on the other hand, is poisoned to a lesser degree, and recovers a major part of the activity with unleaded fuel. Clearly, a platinum catalyst is more resistant to deterioration by the inadvertent use of leaded fuel in a catalyst car. A platinum catalyst may also show better retention of performance, even at the 1975 "unleaded" fuel maximum of 0.05 grams per gallon lead. The advantage of adding palladium to the catalyst for its quicker cold-start "lightoff" is apparently lost when lead is present.

For this, and other reasons, Chrysler has modified the catalyst composition planned for 1975 vehicles to contain a higher percentage of platinum.

Effect of Lead Content on Catalyst Activity

Dynamometer Test Condition

(Same as for previous series, above.)

Catalyst Sample Composition

Experimental samples were made on extruded Corning substrate. Sample size was 6.5" X 3.5" ovals, 3.75" long, combined to make a total bed volume of 150 $in.^3$. The catalyst composition was 70% platinum and 30% palladium at a concentration of 0.2% by weight of the honeycomb support.

A series of tests were run on a standard 70/30 platinum/palladium catalyst composition. Fuels containing different levels of tetraethyl lead were used in a sequence of dynamometer runs. In each test, a fresh catalyst was run on unleaded* fuel for 11 hours. The dynamometer was then run on a fuel containing a specified quantity of lead for another 11 hours. This was followed by operation on unleaded fuel again for an additional 11 to 14 hours.

The results are presented in Figures 7 and 8. Figure 7 shows that the CO activity of the catalyst is promptly lost when leaded fuel is used. The deterioration is from 98 to 93.9 with 46 milligrams per gallon of lead (1975 unleaded fuel level). It becomes progressively worse at higher lead contents, and drops to less than 30% with a fully-leaded fuel containing 3,400 milligrams per gallon (3.4 grams per gallon).

The recovery of activity is equally rapid, though not complete, when unleaded* fuel is again used. Table IV summarizes this data.

Table IV

Lead in Fuel (mg/gal)	Temporary Loss, % Conversion		Permanent Loss, % Conversion	
	CO	HC	CO	HC
10	98	78.4	98.4	79.6
46	93.9	72.9	98.1	79.4
106	91.9	69.1	98.1	79.4
550	85	58.1	96.6	78.1
1100	57	48	95.6	75.0
3400	28	26	88.1	63.7

Figure 8 shows a similar picture for HC activity. Here again, the loss is proportional to the lead content. Both the loss and recovery are fairly rapid, but recovery is less complete for HC oxidation.

*In all instances, the unleaded fuel is indolene clear, containing about 10 mg/gal of lead.

Table IV summarizes the information for both CO and HC. The column headed "Temporary Loss, % Conversion" shows the minimum per cent conversion for these two components at the end of 11 hours. The conversion of both CO and HC are less than 30% effective with a fully-leaded (above average lead content) fuel.

The permanent loss indicates the conversion efficiency after the catalyst has been cleaned up by 11 to 14 hours operation with unleaded fuel. Although the recovery of CO is higher, the normal operating efficiency for this component must be in the 90%+ range to meet 1975-1976 standards.

Chrysler does not have adequate vehicle tests at extended mileage, using fuel with a lead content in the range of .03 to .07 grams per gallon. This is the level being reviewed by the petroleum manufacturers and EPA The manufacturers have urged that the 1975 unleaded fuel level maximum be raised to 0.07 grams per gallon. They consider this a more realistic level of contamination which may occur.

An estimate of the HC which is not catalytically removed, and hence would be emitted in a vehicle, can be obtained by dividing:

$$\frac{100\% - \%\text{ conversion after lead}}{100\% - \%\text{ conversion with no lead}} = \frac{\text{vehicle emissions after lead}}{\text{vehicle emissions with no lead}}$$

From our dynamometer data, laboratory, and car tests, we estimate that there would be about a 10 to 20% increase in HC emissions at all mileages if the average lead content of the fuel used were raised by an average of 0.02 grams per gallon (from a maximum of 0.05 to a maximum of 0.07). The effect on CO emission may be somewhat less. Sufficient car test data are difficult to obtain since the effect of test variation can be eliminated only with extensive vehicle operation. Thus, data published by Esso, Atlantic Richfield, Ford, and Mobil Oil show a progressive decrease in catalyst performance with increasing lead content, using controlled dynamometer tests. Vehicle tests, by these laboratories, in this range of lead content did not show a clear picture.

Calculated Deteioration in Vehicle Emissions Due to the Inadverent Use of Leaded Fuel*

From the data cited in this report, plus other extensive information on catalyst durability, it is possible to calculate the probable loss in catalytic activity and consequent vehicle emission increase. This calculation is more straightforward for the emission of HC, which appears to be mass transport limited in the catalyst bed during most of the standard federal test procedure. The calculation for CO is more complex.

This calculation is considered to be only an estimate and should be confirmed with appropriate vehicle tests. The estimate is shown in Table V, both HC and CO emissions appear to increase similarly.

Table V

Calculated Vehicle Emissions After Use of Leaded Fuel
(Catalyst System Vehicle)

Amount of Leaded Fuel Used, gal.*	Permanent Increase in Vehicle Emissions Due to Lead, %
5	20
10	30
20	50
40	60
65	70
Temporary effect while leaded fuel is used	200-400 (3x - 5x normal)

The permanent loss indicated above is that which would remain after 500 to 1,000 miles of clean-up with unleaded gasoline. Longer mileage with unleaded fuel may minimize this permanent loss somewhat more, though no data are available.

Effect of Various Components of the Tetraethyl Lead Fuel Additive

The relatively rapid poisoning of catalytic activity and rapid recovery therefrom was surprising. Lead is assumed to be a relatively inert solid material, chiefly in the form of lead oxy-halides, lead oxide, and lead sulfate. Such a rapid movment onto and away from the active catalyst sites was surprising.

*Fully-leaded fuel containing about 3 grams/gallon lead.

A quantitative measurement of the lead deposits on the leading edge of the used catalyst monoliths was also informative. The lead content was higher after the unleaded fuel clean-up than it was immediately after the completion of the leaded fuel portion of the test. This indicated that the inactivation while leaded fuel was being run was not principally due to the physical amount of lead on the catalyst. There was actually slightly more lead present after clean-up with unleaded fuel, when much of the activity had been recovered.

We therefore undertook to study the details of this inactivation more completely.

Dynamometer Test Condition and Catalyst Sample Composition

(Test conditions and samples are identical to the previous series discussed.)

A number of single-cylinder engine engine tests were made, individually adding the various components of the commercial TEL additive. It was found that the "motor mix" scavenger, composed of one stoichiometric equivalent of ethyl chloride plus one-half equivalent of ethyl bromide, but no tetraethyl lead, showed serious catalyst inactivation, comparable to that of the total TEL lead additive.

More surprisingly, the use of fuel containing tetraethyl lead, but no halide scavenger, showed very little catalyst inactivation.

In order to quantitatively define these effects, an additional multi-cylinder dynamometer series was run with three different additives: standard TEL - motor-mix scavenger, motor-mix scavenger only, and tetraethyl lead only. The results are shown in Figures 9 and 10.

Figure 9 indicates that the conventional TEL - motor-mix inactivated the catalyst rapidly in 10 hours, to a minimum of about 30% conversion (solid line). As in the previous series, subsequent operation with unleaded fuel recovered most of the activity.

Operation with the ethyl chloride - ethyl bromide scavenger, but no lead, showed even more severe inactivation of the catalyst. CO conversion dropped to about 5% in less than 10 hours. However, subsequent operation with unleaded fuel produced a very rapid and nearly complete recovery.

The use of tetraethyl lead with no scavenger resulted in a very slight decrease in catalyst activity, which did not subsequently recover with unleaded fuel.

In all of these tests, the level of lead and scavenger was equivalent to that in a fully-leaded fuel containing 3 grams per gallon lead.

Figure 10 shows a very similar picture for the catalytic conversion of HC. It is quite apparent that it is the ethyl chloride-bromide scavenger which is principally responsible for the inactivation of this type of noble metal catalyst. There appears to be only a slight permanent loss in activity from tetraethyl lead, without scavenger.

According to these results, it is not the lead in automotive fuel which inactivates a noble metal catalyst, but rather the halide scavenger.

Unfortunately, it is not feasible to operate an engine on leaded fuel without the scavenger, since lead oxides accumulate excessively on the sparkplug and in the combustion chamber.

It is possible that the halide scavenger forms halide salts with the platinum-palladium, which are not catalytically active. These are decomposed when the scavenger is no longer present in the fuel, and catalytic activity then returns.

The lead oxide - lead sulfate produced when lead, but no scavenger is used, is an inert solid which covers the catalyst sites physically, to a small degree. This coverage and loss of activity is relatively permanent. With palladium we have indications that the lead oxide permanently reacts to inactivate this catalyst. This does not appear to be the case with platinum.

One answer to the problem would be to discover a scavenger for lead which does affect the precious metal catalyst. At present, such a scavenger is unknown, and may not be feasible. An alternate option is to use the manganese additive for octane improvement which has been developed by the Ethyl Corporation, and which does not require a halide scavenger. It appears that this additive does not inactivate a noble metal catalyst. The deficiency in this additive is its high cost and less efficient improvement of fuel octane.

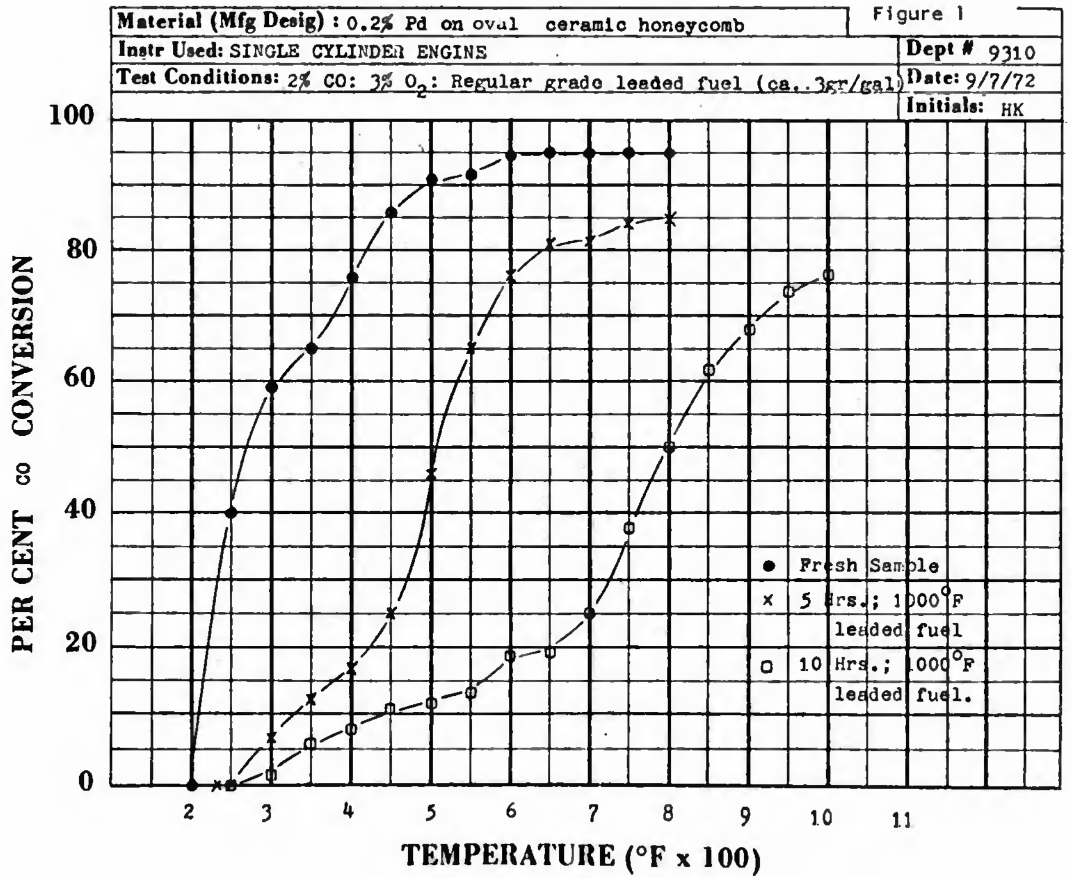


Figure 1
Material (Mfg Desig) : 0.2% Pd on oval ceramic honeycomb
Instr Used: SINGLE CYLINDER ENGINES
Test Conditions: 2% CO: 3% O_2: Regular grade leaded fuel (ca. 3gr/gal)
Dept # 9310
Date: 9/7/72
Initials: HK
PER CENT CO CONVERSION
100
80
60
40
20
0
2
3
4
5
6
7
8
9
10
11
TEMPERATURE (°F x 100)
● Fresh Sample
× 5 Hrs.; 1000°F leaded fuel
□ 10 Hrs.; 1000°F leaded fuel.

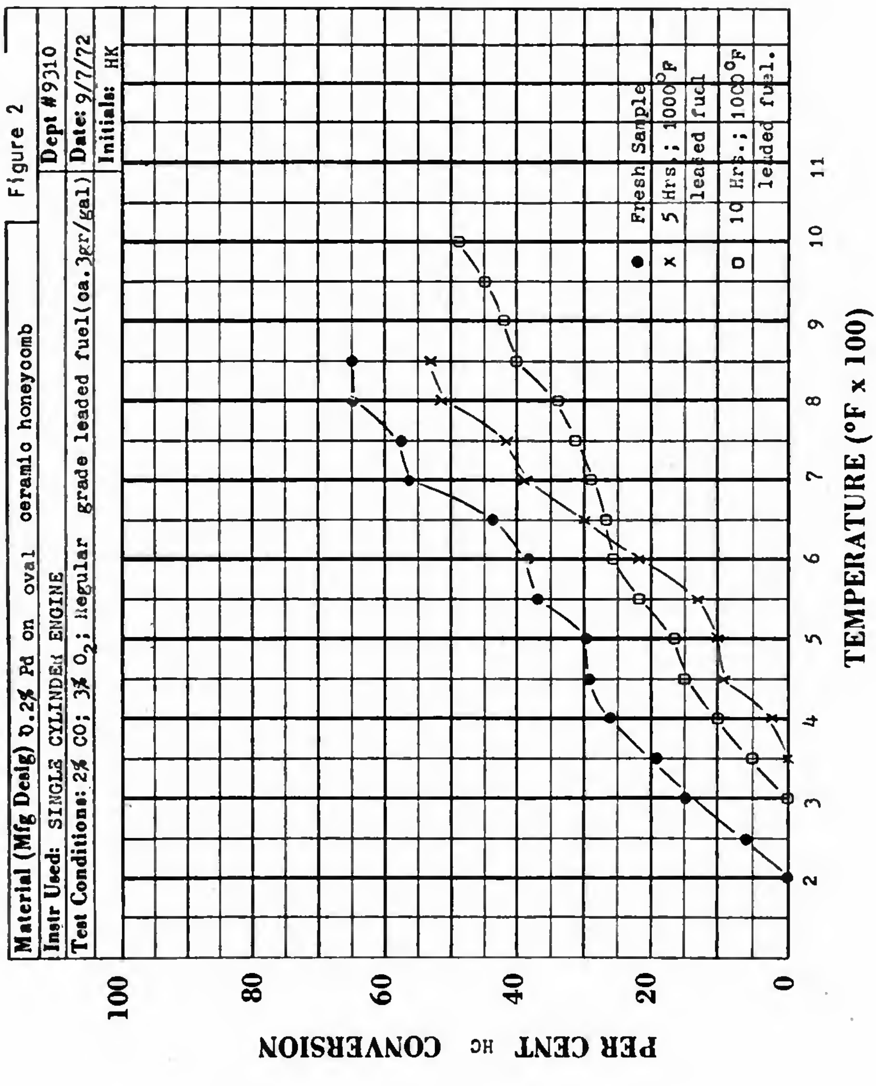


Figure 2
Material (Mfg Desig) 0.2% Pd on oval ceramic honeycomb
Instr Used: SINGLE CYLINDER ENGINE
Test Conditions: 2% CO; 3% O2; Regular grade leaded fuel(ca. 3gr/gal)
Dept #9310
Date: 9/7/72
Initials: HK
Fresh Sample
5 Hrs.; 1000°F leaded fuel
10 Hrs.; 1000°F leaded fuel.
PER CENT HC CONVERSION
0
20
40
60
80
100
TEMPERATURE (°F x 100)
2
3
4
5
6
7
8
9
10
11

Figure 3

OXIDATION CATALYST ENDURANCE TESTS

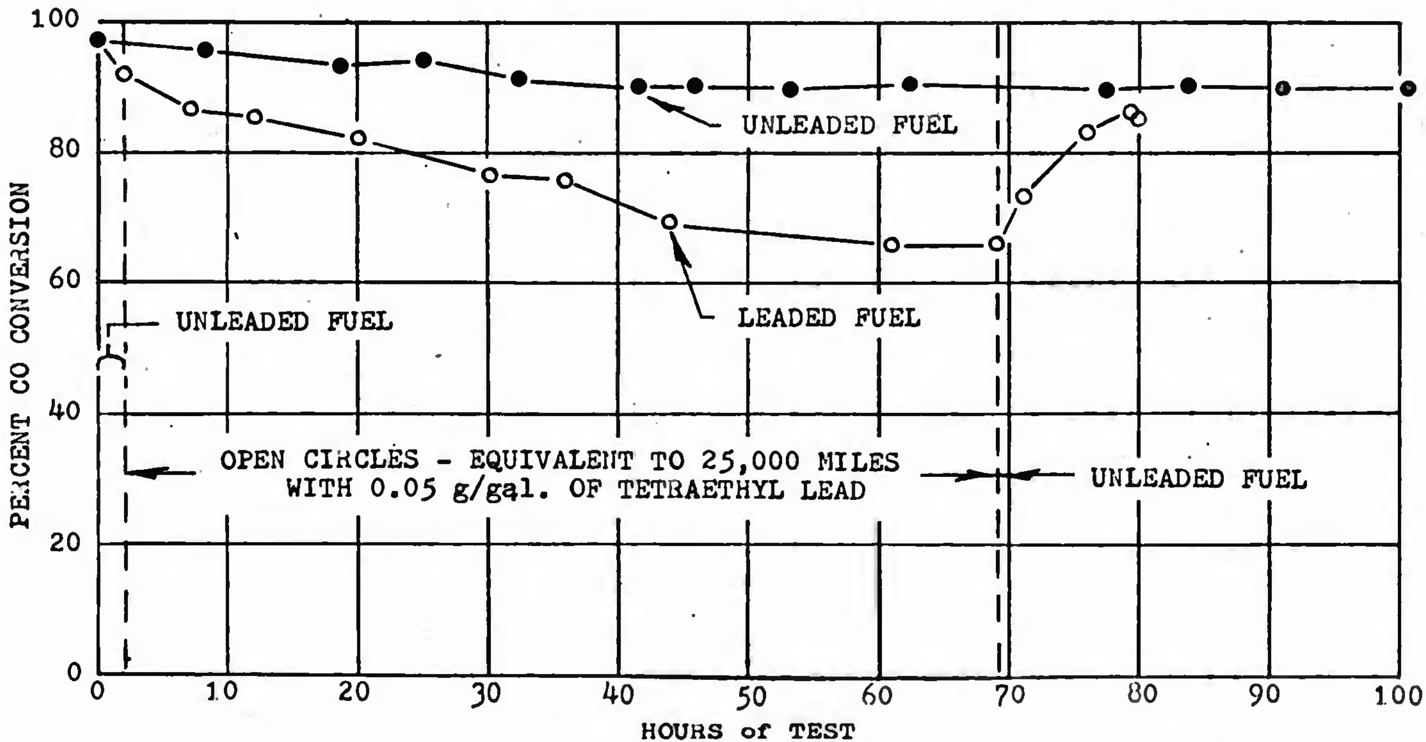


Figure 4

OXIDATION CATALYST ENDURANCE TESTS

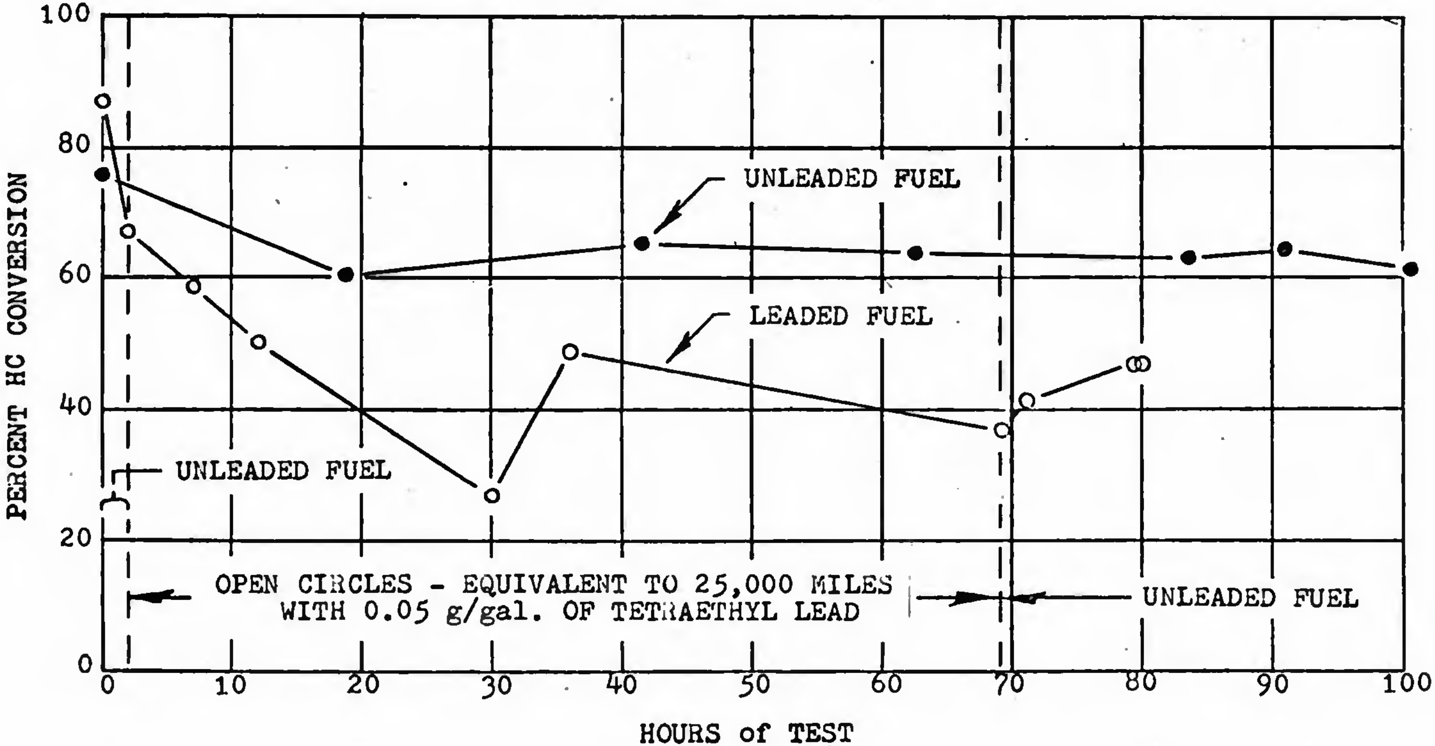
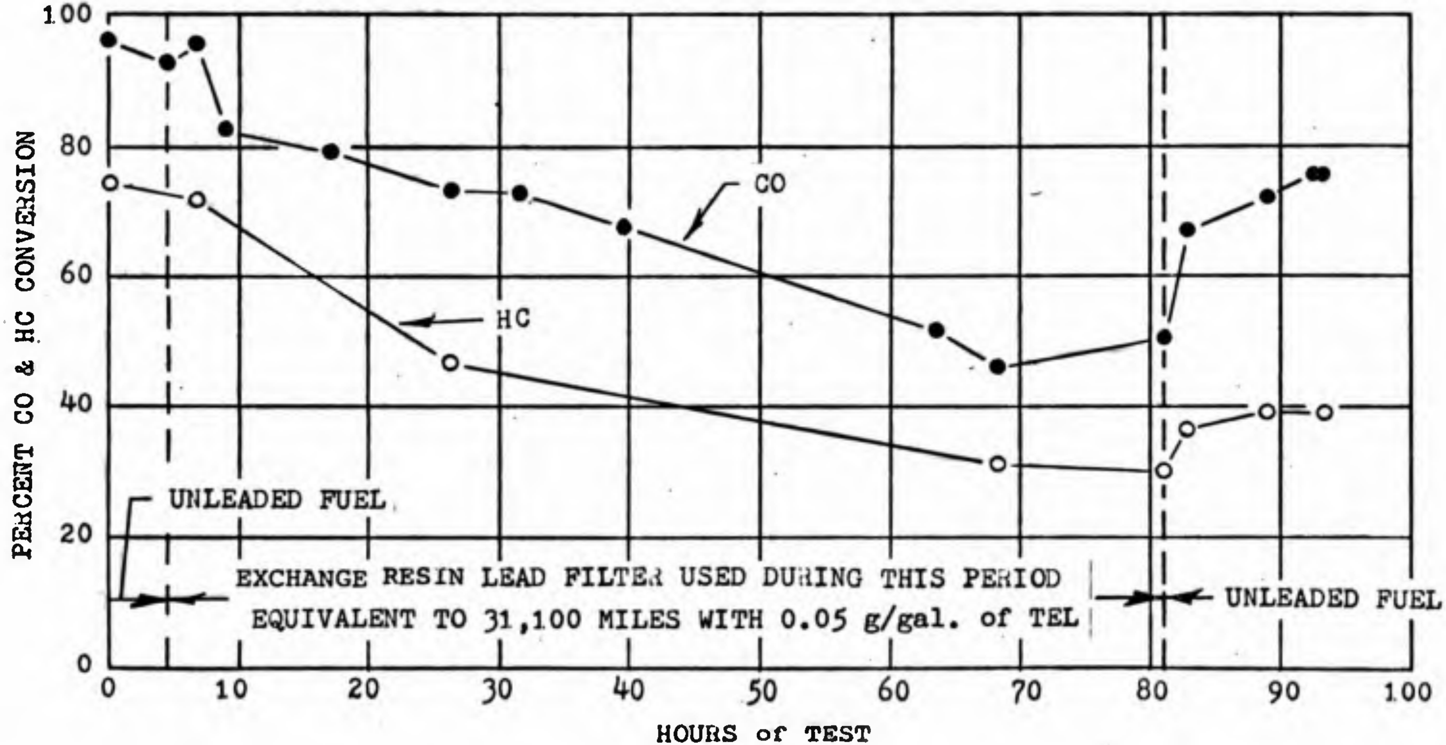


Figure 5

OXIDIZER CATALYST ENDURANCE TEST
EXCHANGE RESIN LEAD FUEL FILTER



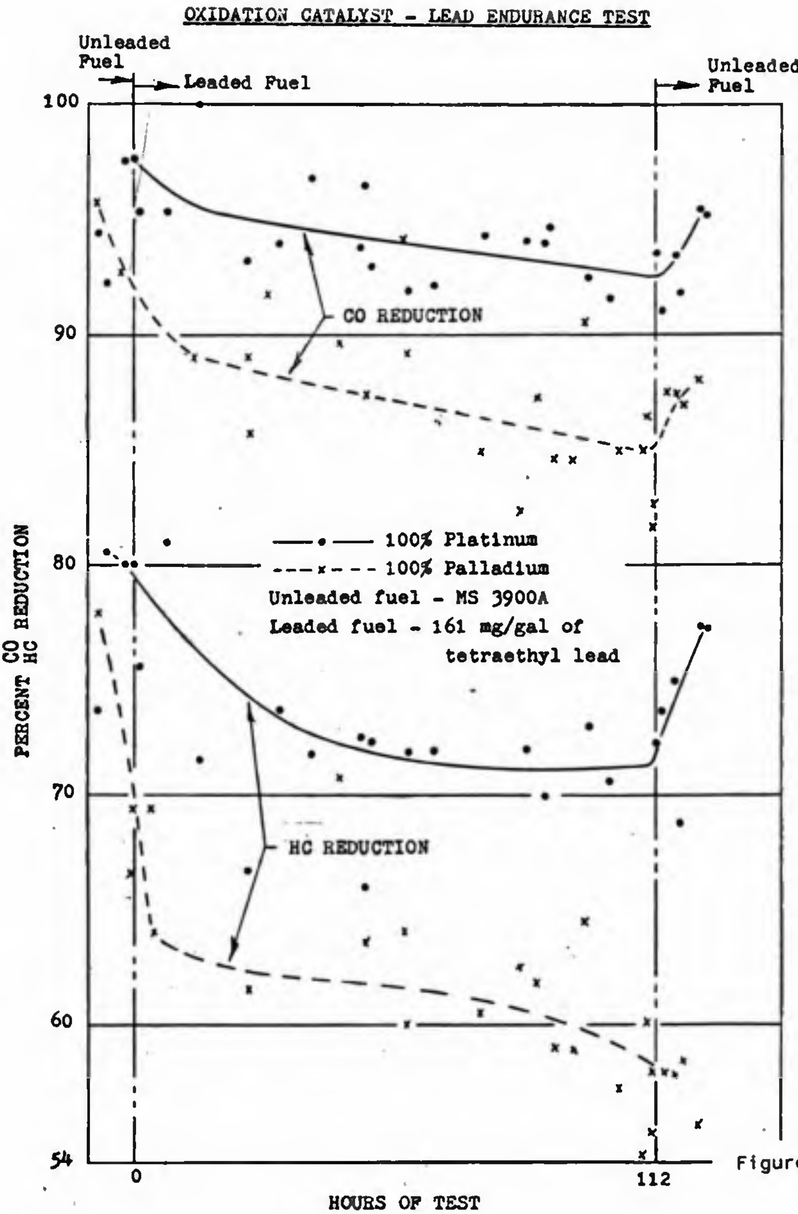

OXIDATION CATALYST - LEAD ENDURANCE TEST
Unleaded Fuel
Leaded Fuel
Unleaded Fuel
100
90
80
70
60
54
PERCENT CO HC REDUCTION
CO REDUCTION
HC REDUCTION
100% Platinum
100% Palladium
Unleaded fuel - MS 3900A
Leaded fuel - 161 mg/gal of tetraethyl lead
0
112
HOURS OF TEST

Figure 6

OXIDATION CATALYST - LEAD POISONING TEST

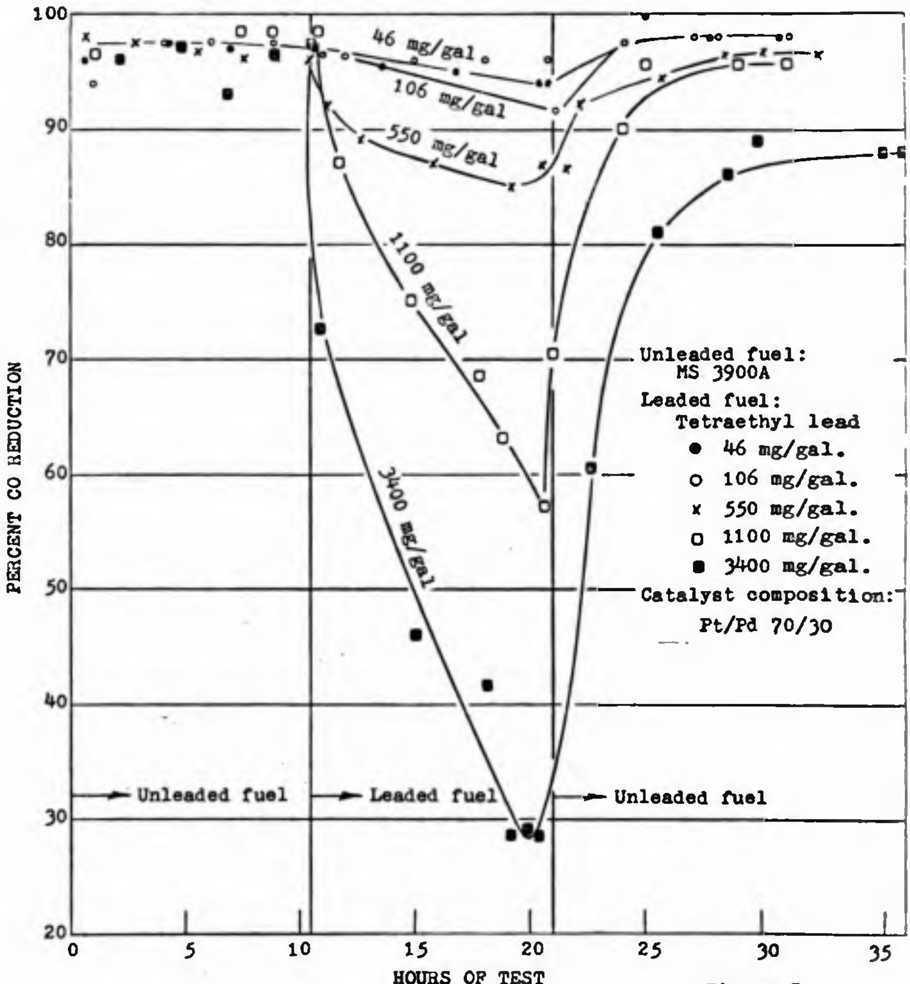


Figure 7

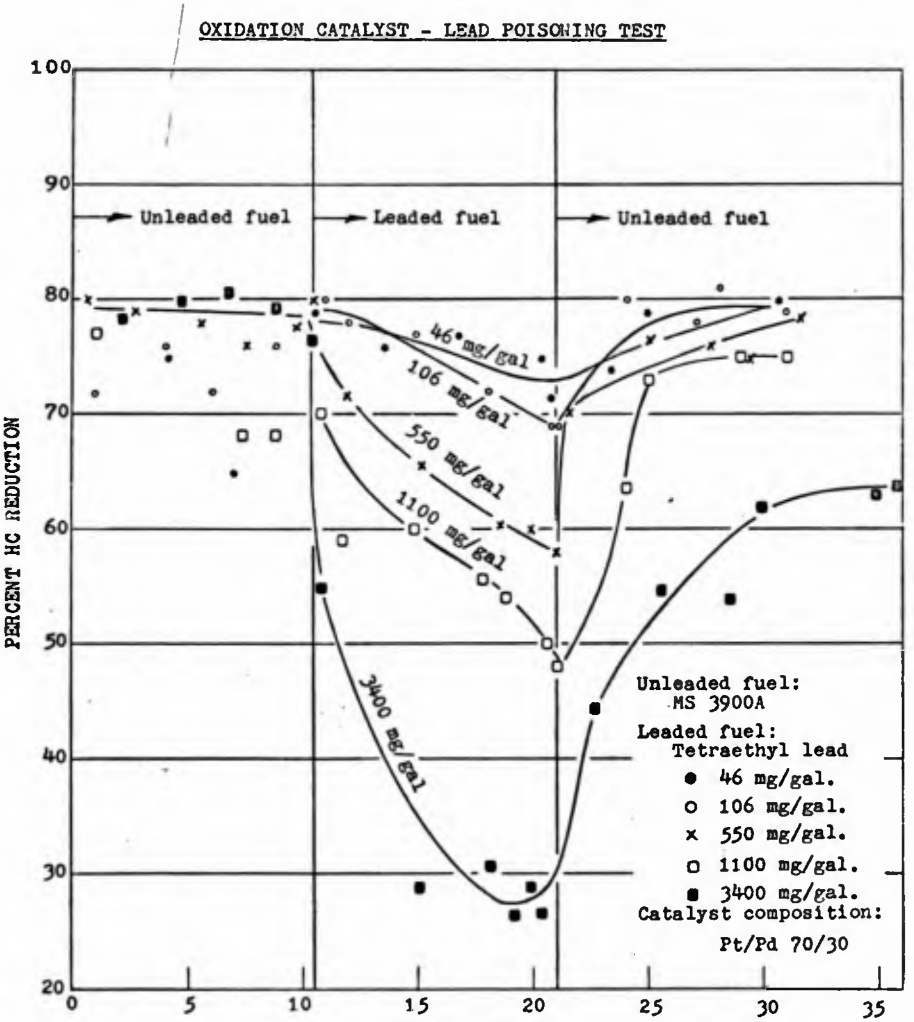

OXIDATION CATALYST - LEAD POISONING TEST
PERCENT HC REDUCTION
HOURS OF TEST
Unleaded fuel
Leaded fuel
Unleaded fuel
46 mg/gal
106 mg/gal
550 mg/gal
1100 mg/gal
3400 mg/gal
Unleaded fuel:
MS 3900A
Leaded fuel:
Tetraethyl lead
46 mg/gal.
106 mg/gal.
550 mg/gal.
1100 mg/gal.
3400 mg/gal.
Catalyst composition:
Pt/Pd 70/30

Figure 8

OXIDATION CATALYST POISONING TESTS

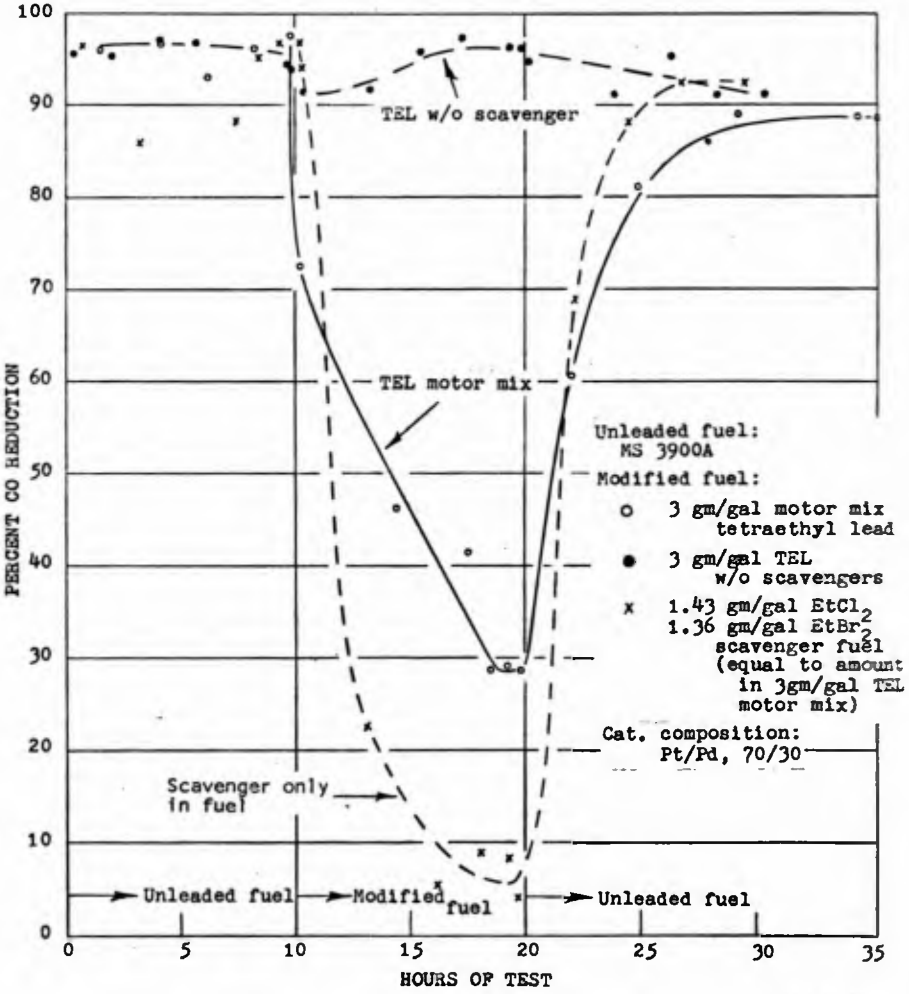


Figure 9

OXIDATION CATALYST POISONING TESTS

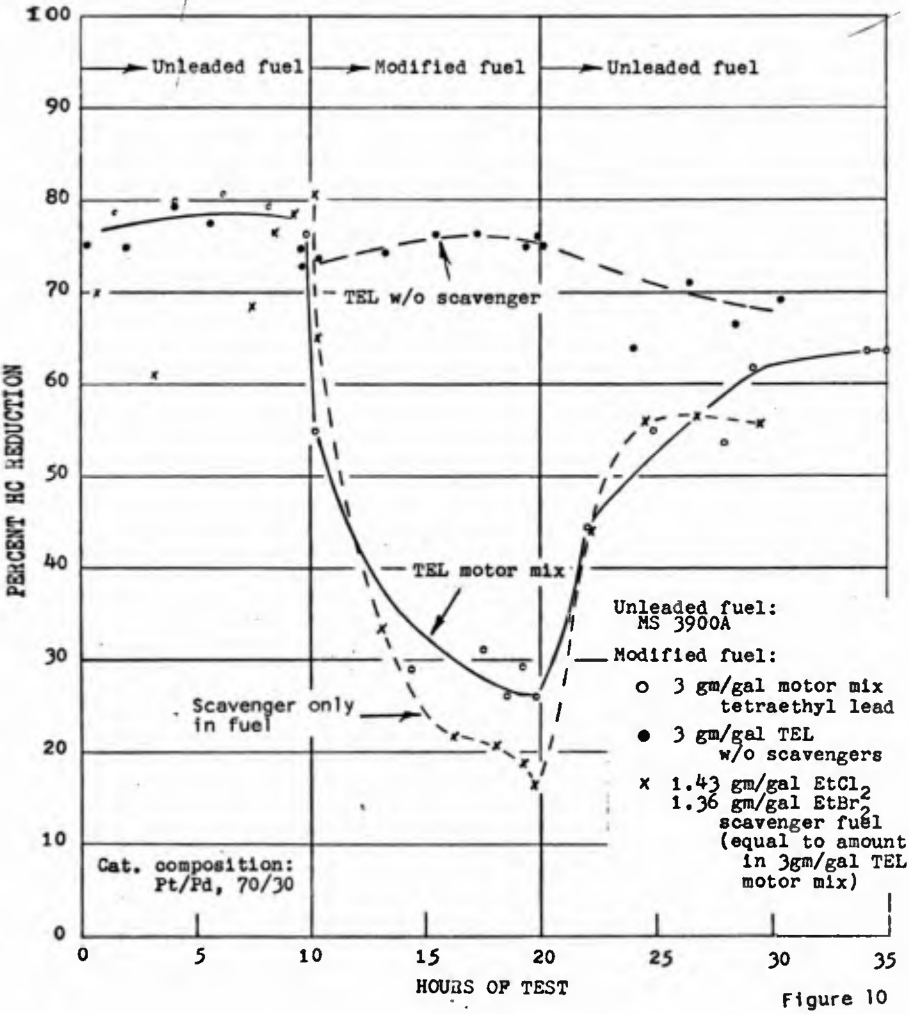


Figure 10

EXCERPTS FROM EVALUATION OF CATALYSTS AS AUTOMOTIVE EXHAUST TREATMENT DEVICES

Report of the Catalyst Panel to the Committee on Motor Vehicle Emissions, National Academy of Sciences, Revised March 28, 1973

DEACTIVATION

All proposed oxidation catalysts start as finely divided crystallites deposited on a particulate or monolithic support. Recrystallization into larger particles is ordinarily thermodynamically favored. Further, new phases may be formed by reaction among the catalytic ingredients or between the ingredients and the support. For example, NiO may react with alumina to give a spinel (4). All of these effects will ordinarily reduce the availability of the active ingredients and, thus, catalytic activity. It is the art of the catalyst manufacturer to minimize the occurrence of these undesirable reactions. Such information is almost always proprietary.

At low temperatures, the rate of oxidation is determined by rates of adsorption, desorption, and surface reactions. At high enough temperatures, rates of the surface reactions become fast, and severe concentration gradients develop within the porosity of the catalyst leading to mass transfer controlled reactions. Much of the active ingredients sees little or no reactants and catalytic activity falls substantially below that of an ideal, fully exposed catalyst. Change in texture will affect this phenomenon. The range of transition temperatures between the two modes of operation is probably unknown for many of the oxidation catalysts and NO_x catalysts.

In general, in terms of measured emissions, catalyst deactivation is rather substantial during the first 1,000 to 3,000 miles. An interpretation of the nature of the deterioration is difficult because of the complicated nature of the EPA cycle. In most cases, the increased emissions may result largely from an increase in the light-off temperature, i.e., most of the increase occurs during cold start. However, increasing breakthrough of concentration spikes or a general increase in the emission level may also be substantial.

Following this initial decline, the activity of most catalysts tested may continue to decline at a slower rate. It is doubtful that any general conclusions can be reached at this time.

POISONING

There is ample evidence that lead can result in poisoning of oxidation catalysts. The variability problem discussed above makes it difficult to set a reliable upper limit on the maximum permissible content in lead. It appears that the effect of 0.01 g per gallon of lead would be of little consequence in comparison with other types of deterioration. It is probable that many catalysts would not be too adversely affected by 0.03 g. The problem is complicated by the fact that lead may be volatilized from some catalysts during driving modes that result in high catalyst temperatures. The UOP Miniverter is reported to recover from occasional exposure to leaded fuel (1). The Gulf NO_x catalyst is claimed to work on leaded fuel and there is some suggestion that the Gould thin metal honeycomb may tolerate lead. However, no prolonged vehicular tests on these catalysts have been reported to us. In the presence of phosphate, some lead is deposited in the relatively innocuous form of lead phosphate (14).

Sulfur is an omnipresent component of gasoline and has been reported to poison oxidation catalysts. Again, however, SO_2+SO_3 may volatilize from some oxidation catalysts during driving modes giving high catalyst temperatures (1, 2). This is apt to be particularly true of noble metal catalysts. Platinum, after all, is a catalyst for the oxidation of SO_2 (18). It is difficult at this stage to set a general upper limit for permissible S content in gasoline. Each catalyst may accept a different level of S (See Chapter 5). Current data indicate that 100 ppm of S can be accepted regardless of whether the oxidation catalyst is noble metal or base metal as long as a temperature of 1350–1400°F is reached periodically.

The minimum average operating temperature of base metal catalysts may be determined by the decomposition temperature of a base metal sulfate; a UOP catalyst exhibits sulfate formation below about 1100°F with a 0.01 weight percent sulfur fuel and below about 1200°F with a 0.1 weight percent sulfur fuel (1). Sulfur poisoning by sulfate formation is largely reversible; a deactivated catalyst may be restored by heating to 1500°F (1), which corresponds to expected gas temperatures at 70 mph (UOP) or 90 mph (Chrysler, GM) (2, 11).

Both phosphorus and zinc, common additives to lubricating oil, have been reported to collect on certain catalysts, and it has been reported that phosphorus is a poison (19). However, we have seen no data establishing a clear difference between ashless and conventional lubricating oils in actual vehicular testing.

For noble metal catalysts, the ease of hydrocarbon oxidation increases in the following sequence:

$$\text{methane} < \text{ethane} < \text{other alkanes} < \text{aromatic hydracarbons} < \text{olefins} < \text{acetylenes}$$

During gradual deterioration, the increase in emissions of HC is not apt to be in olefins and acetylenes but rather in the less reactive types of hydrocarbon. Combustion of methane may be incomplete even on fresh catalyst.

FAILURE MODES

In addition to progressive deterioration, a catalyst may suffer abrupt failure. Catalysts on particulate supports, catalysts on monolithic supports, and thin metal catalysts behave rather differently.

All will melt if the temperature rises too high (alumina pellets, 3700° F; monoliths and Monel metal, about 2400–2500°F, depending on type.) Clearly, actual melting of alumina pellets will be difficult. Melting of the other two types has been regularly observed in testing (2, 15, 16). System and catalyst must be mated so that this will not occur under any permissible driving mode and, insofar as possible, under system malfunction. The destruction temperatures of monolithic oxidation catalysts and thin metal catalysts are reached in the presence of excess CO and unburned hydrocarbon at a particular part of the catalyst. Such conditions may be caused by protracted misfires (1), high speeds coasting on long downhill grades (2), and poor catalyst design (16). In at least one case, the melting of a monolist has been reported to be due to maldistribution of the catalyst component, a local high rate of heat generation in a region with low melting points: e.g., w/CuO, mp 975°C versus 1350°C for monolith support.

Thin metal structures that are exposed to substantial excess oxygen when hot (such as when the vehicle runs out of gasoline at 70 mph) can, in essence, burn up. Some sources believe that a catalyst cannot reach melting temperature; other sources believe that a temperature overload valve will be needed.

In addition, temperatures below the melting points may cause rather rapid catalyst deactivation. Pellets may lose area, convert to α—Al_2O_3, or clump and develop excessive back pressures. Some particulate supports of stabilized γ—Al_2O_3 appear to resist 2000°F for short intervals, but continued operation at such temperatures leads to rapid failure. This is partly a matter of the physical properties of the catalyst and partly a matter of containerization. Advances in technology appear to have made attribution failures less common.

Insofar as the support itself is concerned, monoliths are less sensitive to temperatures than are particulate supports, short of melting or sagging temperatures. However, high temperatures may lead to rapid deactivation because of reactions involving the catalytic compouents. The upper permissible temperature for both particulates and monoliths will depend on the actual catalyst, not just on the support (14).

Monoliths may also crack under thermal cycling and certain forms of monoliths, particularly the spiral wound, may delaminate destructively. The more recently manufactured extruded monoliths seem to have less tendency to such failure (17).

Monel metal catalysts are subject to embrittlement by grain boundary growth and subsequent disintegration (7). Gould claims that its new catalyst preparations are resistant to this effect but we have seen no test data.

Monoliths are subjected to fracture and disintegration caused by vibrations if they are not hold snugly in their containers at all operating temperatures (17).

SUMMARY

Operating ranges for NO_x reduction, oxidation, and three-way catalysts are defined by intervals of temperature, gas composition, gas flow rates, and concentration of catalyst poisons.

The limits of such operating windows are relatively well developed for oxidation catalysts; NO_x reduction catalysts are far less understood at present. This position is probably due to the short history of NO_x reduction chemistry compared with that of hydrocarbon and CO oxidation.

Lead, sulfur, and phosphorus are the major poisons in exhaust gases; the influence of minor constituents is not well established. Variability in test results poses serious problems in the study of the rate of catalyst deactivation and of the effects of poisons.

Catalyst failure modes have been examined in terms of the underlying thermal and chemical behavior of catalyst components. (Methods of avoiding failure are discussed in Chapter 5).

* * * * * * *

POISONS

The major catalyst poisons are lead, sulfur, and phosphorus. The poisoning of a catalyst by these elements depends primarily on three conditions: the Pb, S, and P levels in the gasoline and motor oil, the average operating temperature of the catalyst bed, and the chemical elements in the active component of the catalyst.

As a basis of discussion, the chart below indicates the total possible emissions of lead, phosphorus, and sulfur over 50,000 miles for a conventional oil (API service "SD" oil) and two fuels (the latter is the proposed EPA fuel specification):

	G per 50,000 mi
Oil Component (wt %):	
Phosphorus (0.13)	54
Sulfur (0.35)	145
Sulfated ash (1.3)	540
Fuel Component:	
A. Phosphorus (0.07 g/gal)	350
Sulfur (0.04 wt %)	5520
Lead (0.07 g/gal)	350
B. (Proposed EPA 1975)	
Phosphorus (0.01 g/gal)	50
Sulfur (?)	----
Lead (0.05 g/gal)	250

Assumptions:
Oil consumption: 1,000 mi/qt
Fuel consumption: 10 mi/gal
Components: as indicated above

Lead

Lead is an efficient poison of noble metal catalysts. The halide scavengers associated with motor mix (tetraethyl lead plus scavengers) are known to deactivate metal oxide oxidation (17) and NO_x(18) catalysts. Thus, reduction of lead and associated scavengers should benefit essentially all catalytic systems. Most of the earlier research on lead poisoning did not include detailed studies at very low lead levels (less than 100 mg/gal) (19). A very tentative evaluation can be based on a recent durability study (20) of the influence of lead on hydrocarbon oxidation by a platinum monolith at 800° F. Catalyst activity declined to a plateau value after about 100–200 hr of aging in engine exhausts (1000 to 1250° F, cycling oxidizing and reducing conditions). Little recovery was evident on replacement of the leaded gasoline by lead-free gasolines. The percentage of initial hydrocarbon oxidation activity at 800° F remaining after 500 hr of aging was about 83 percent, 70 percent and 62 percent for lead levels of 3, 35, 70 mg Pb/gal respectively. (See Figure 2). A simple extrapolation to 0 mg Pb gal suggests that the catalyst lost 15 percent of initial activity for reasons other than lead. It appears that each mg Pb/gallon will result in loss of 0.5 percent of initial hydrocarbon oxidation activity after 500 hr of aging under typical conditions (1000–1250° F, oxidizing and reducing).

By comparison, previous proposed maximum lead levels in lead-free gasolines for 1975–76 are higher:

20 mg Pb/gal (GM) (21).
50 mg Pb/gal (EPA) (22).
70 mg Pb/gal (ASTM, proposed revision) (23).

The proposed level of lead is probably below what the ASTM and the Army believe will be found as a typical lead contaminant level "which results from contamination when good refinery and distribution practices are followed" (23).

Sulfur

The previous mentioned Ford study (20) also examined the effects of low levels of sulfur (0.02 wt %, 0.07 wt %, 0.12 wt %) on NO_x conversion efficiency for up to 200 hr in the presence of 50 mg Pb/gal, the proposed EPA level. After 100 hr, the NO_x activity diminished to a plateau of about 75, 44, and 36 percent of the initial value. A curve through the three points (plateau NO_x efficiencies versus percent sulfur) passes through 100 percent at zero percent sulfur.

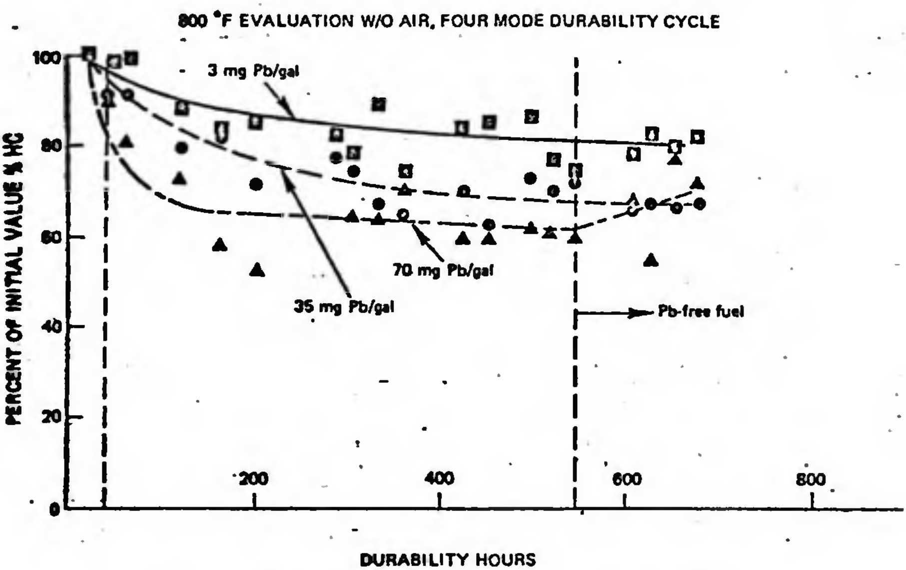


FIGURE 2.—*Effect of Lead on Oxidation Catalyst Efficiency*

* * * * * * *

FAILURE INDICATORS

The need for failure indicators is well recognized. While there are some ideas on such devices, there have been no experimental demonstrations. It is particularly difficult to design a short test on an automobile with a warmed-up engine and catalyst to simulate the EPA cold-start test procedure.

Overtemperature

Thermo-sensors are obvious choices, but their durability in exhaust systems is not established. UOP has informally suggested a pyrometric plug in the oxidation reactor wall: Overtemperature would melt the plug, resulting in an audible whistle (5).

Deactivation

UOP suggests a service station test for the oxidation bed: Short one spark plug, measure hydrocarbon emission (idling engine); if HC emission is less than 50 ppm, OK; above 50 ppm, deterioration; above 500 ppm, dead (25).

* * * * * * *

RECYCLE OF CATALYTIC MATERIALS

The low costs and relatively large supplies of substrate materials and base metal catalytic components make it unrealistic to consider reclamation of these materials. However, recovery and recycling of noble metal from used exhaust catalysts can have a significant impact on the annual requirements for new supplies. At levels of 0.7 oz/car, recovery of the noble metal is feasible; it is doubtful if levels below 0.05 oz/car (this corresponds to a value of about $7 of the noble metal at today's prices) could be economically reclaimed. Figure 5 shows the amount of new platinum that would be required each year until 1990 assuming 0, 50, 75, or 90 percent recovery of the noble metal (3). These data assume a platinum loading of 0.7 oz/car and a 50,000-mile durability. If the converters must be recharged in less than 50,000 miles, the noble metal consumption will be even larger than indicated.

TOXICITY OF AUTOMOBILE EXHAUST CATALYSTS

Almost all the materials being considered as components in automobile exhaust catalysts are somewhat toxic. Table 8 lists several of these materials and their relative toxicities. Selected data were taken from Sax's *Dangerous Properties of Industrial Materials* (6), and in most cases the toxicity values apply to several "respresentative" compounds that contain each particular metal. Sax defines toxicity as "the ability of a chemical molecule or compound to produce injury once it reaches a susceptible site in or on the body."

* * * * * * *

The two major divisions of Table 8 refer to the length of exposure to the compound, with "acute" meaning of short duration (seconds, minutes, hours) and "chronic" meaning long or repeated exposure (days, months, years). The subdivisions refer to the location of the harmful effect, with "local" meaning action limited to the point of contact and "systematic" meaning action occurring at places other than the point of contact. The toxicity values range from nontoxic (0) to severely toxic (3); the symbol U is used when the toxicological effect is unknown.

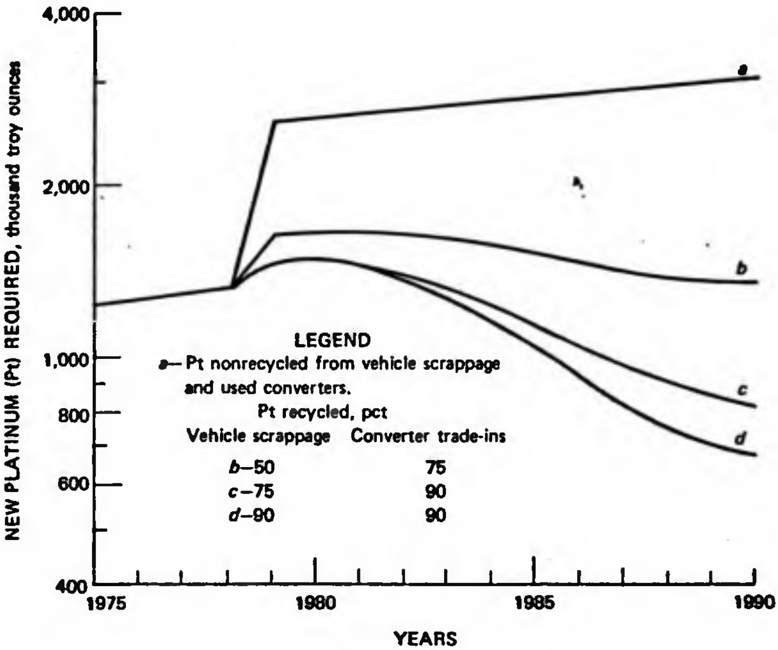


FIGURE 5.—*Estimated new platinum demand annually at several assumed percentages of platinum recycled from scrapped light-duty vehicle converters and converter trade-ins (assuming a converter life of 50,000 miles)*

TABLE 8.—TOXICITY OF SOME COMPOUNDS THAT MIGHT BE USED IN AUTOMOBILE EMISSION CONTROL CATALYSTS

Compound	Acute		Chronic		Maximum allowable concentration in air (mg/M³)
	Local	Systemic	Local	Systemic	
Lead compounds	0	3	0	3	0.15
Chromium compounds	3	U	3	3	.1
Nickel compounds	1	1	2	2	.5
Nickel carbonyl	3	3	1	3	
Manganese compounds	U	2	U	3	15.0
Copper compounds	1	2	1	1	
Metal carbonyls	3	3	U	3	
Alumina	1	0	2	0	
Silica	2	0	3	1	
Cobalt compounds	1	1	1	1	.5
Tungsten compounds	U	1	U	1	
Magnesium compounds	1	2	2	0	15.0
Ruthenium compounds	(1)	(1)	(1)	(1)	.01
Ruthenium tetroxide	2	U	U	U	
Platinum compounds	(2)	(2)	(2)	(2)	(2)
Palladium compounds	(2)	(2)	(2)	(2)	(2)
Mercury					.1

[1] Details unknown, but probably toxic.
[2] Very low toxicity.

Source: Sax, 1963 (refs. 6,7).

Note: 3—very toxic; 2—moderately toxic; 1—slightly toxic; 0—nontoxic; U—unknown toxicity.

There are three possible sources of toxicological danger associated with automobile exhaust catalysts: In emissions of the material into the atmosphere during automobile operation, in the manufacture of the catalysts, and in the installation of the catalysts in the automobiles.

Most of the compounds listed in Table 8 are low vapor pressure solids that can only escape from the exhaust system as very fine airborne dust particles formed by catalyst attrition. The predominant mechanism for incorporation into the body would be by inhalation of contaminated air. A few compounds, such as metal carbonyls and ruthenium tetroxide, are liquids under ambient conditions and have boiling points less than 100° C. While not present in the original catalyst, these compounds might be formed by reaction with the exhaust gases and emitted into the atmosphere in the vapor state (16, 17). Fortunately, these compounds decompose at relatively low temperatures, so even if they were formed in the converter, they would probably decompose before they escape. The only time significant emission is likely to occur is during warm-up after a cold start.

In actual practice, tests with monel catalysts (Cu-Ni alloys) have shown no evidence for emissions of significant quantities of $Ni(CO)_4$. Ruthenium is slowly depleted from reduction catalysts, and this is presumed to occur through formation of RuO_4 when the catalyst is used under oxidizing conditions during cold start operation (17). Most companies who favor use of ruthenium are working on ways to avoid RuO_4 formation, and it is hoped that this problem can be adequately solved (17, 18).

Regarding actual measurement of particulate emissions from catalysts, GM has reported tests with and without base metal catalysts, using either leaded or unleaded gasoline (17). The results are summarized in Table 9. The primary source of particulate matter is due to the lead in the gasoline, although comparison of the last two rows of the table indicates that some particulate matter may come from the catalyst as well. Assuming the upper limit on particulate matter from the catalyst (0.02 g/mile), this corresponds to about 1 lb./20,000 miles. However, it is thought that monolithic and pelleted catalysts that have been "stabilized" and "pre-attrited" will give particulate emissions far below the values observed in this test. Even at worst the projected catalyst particulate emissions are an order of magnitude less than the present lead emissions, and Table 8 indicates that none of these materials is much more toxic than lead. It is therefore concluded that there will be no significant toxicological hazard from particulate emissions of any of the materials now being seriously considered for use in automobile exhaust catalysts.

For years catalyst companies have been safely manufacturing materials far more toxic than these proposed exhaust catalysts, and it is thought that toxicological dangers associated with production of these materials can easily be avoided. However, installation and replacement of these materials in the cars may pose the greatest danger. It is quite likely that dust particles from the catalysts will be formed during such an operation, particularly in the case of beaded or extruded catalysts. This could create a hazardous environment for the mechanic who may carry out many such operations daily. Chromium compounds are particularly dangerous, as chromate salts have been associated with cancer of the lungs (6, 7). Special installation techniques may have to be imposed to protect the mechanics.

TABLE 9.—PARTICULATE EMISSIONS FROM AUTOMOBILES

Gasoline	Catalyst	Particulate emissions (gm/mile)
3 gm Pb/gal	None	0.2 to 0.3.
No Pb	do	0.01.
Do	Base metal pellets	0.01 to 0.03.

Source: Klimisch, 1972 (reference 2).

Excerpts From Environmental Protection Agency Proposed Methodology for Assessing Availability of Technology for Meeting 1975 Motor Vehicle Emissions Standard

Proposed for comment as part of the proceedings by the Environmental Protection Agency to consider applications by five motor vehicle manufacturers for suspension of the effective date of the 1975 motor vehicle emission standards—March 9, 1973

INTRODUCTION TO METHODOLOGY DISCUSSION

The methodology presented and discussed here constitutes a proposal. It is subject to revision upon the basis of the oral and written comments introduced into the record of the pending proceeding upon the applications of five new motor vehicle manufacturers for a one-year suspension of the effective date of the 1975 emission standards applicable to such vehicles.

This proposed methodology was developed prior to receipt of the applicants' updated applications. It attempts to take into account those criticisms and suggested revisions of the methodology used in the Technical Appendix to the Administrator's Decision of May 12, 1972, which were thought to be meritorious. This was done to provide the applicants and other participants in the proceeding with maximum time to develop and submit comments on the methodology which EPA should us in making a final decision on suspension of the 1975 emission standards.

EPA has been unable to analyze in depth the methodologies submitted by Ford Motor Company, Chrysler Corporation, General Motors Corporation, International Harvester Company, and American Motors Corporation in their post remand submissions and to revise EPA's proposed methodology as would appear warranted by this analysis. Of course, such an analysis will be undertaken prior to the final decision. In addition, EPA invites testimony at the public hearings and written comments for the record for the purpose of determining the most appropriate methodology to be employed at the time of the Administrator's final decision.

To a large degree, the final methodology will depend on the data which is available in the record to quantify the effects of the various factors which must be considered. An absence of reliable data has in some cases necessitated the proposed use of factually unsupported assumptions in this proposed methodology. These assumptions have been developed, however, to reflect the expert judgment and past experience of the Agency's technical personnel. Comments and data are particularly solicited on those aspects of the methodology as to which an absence of reliable data has necessitated the use of assumptions or factually unsubstantiated correction factors. Any person who participates in the suspension proceeding by written submission or oral statement shall be deemed not to take issue with the nature, scope, or dimension of the assumptions and correction factors used in this methodology, unless express disagreement, the basis therefor, and alternative assumptions or correction factors have been registered by such participant.

The proposed methodology only treats the question of the availability of effective technology to permit a given vehicle to obtain certification of conformity with the 1975 emission standards. The issue of what is the most appropriate methodology for predicting the availability of effective technology for new motor vehicles on the assembly line and in use will be addressed subsequently. Comments and data relating to these issues are also solicited.

BASIC DESCRIPTION OF THE METHODOLOGY

To determine the capability of a manufacturer to certify for model year 1975, this methodology follows the 1975 certification process whenever possible. In certification, a test fleet is selected by EPA based on a manufacturer's planned product line. The product line is divided into engine-system combinations, each of which must demonstrate its ability to meet the standards through test results taken during 50,000 miles of durability. A minimum of one vehicle per engine-system combination is selected for durability, although a manufacturer may test additional vehicles and combine the results. A deterioration factor (DF) is derived from the durability vehicles as a measure of the system effectiveness over its useful life (50,000 miles). The interpolated 4,000- and 50,000-mile points from the DF calculation must be below the standard.

This methodology will describe the method that will be used to determine DF's for a manufacturer's 1975 product line based on his testing of prototype vehicles.

Certification also requires selecting emission-data vehicles and determining their 4,000-mile emission levels. These emission levels are adjusted using the DF and compared with the standards to determine whether an engine family meets the certification requirements.

This methodology will discuss techniques used to select emission-data vehicles from a manufacturer's product line and techniques used to compare them to the standards for 1975. For the purposes of this methodology, each vehicle will be assumed to be in a different engine-system combination, unless proven otherwise in data submission.

* * * * * * *

ADJUSTMENTS TO THE DATA

In many cases the set of data available to EPA will be less than ideal. Only when a manufacturer has accurately tested a fully developed maximum effort system calibrated for the 1975 Federal standards using .03 grams of lead per gallon on the AMA mileage accumulation schedule will the use of adjustment factors be obviated.

The exact method for employing these factors will depend on the characteristics of each set of data available. In some cases it will be possible ot calculate the 4000 mile X DF values or the extrapolated 50,000 mile values first and then apply adjustments, while in other cases individual data points may have to be adjusted before a DF can be calculated. Some combination of the above may also be necessary.

Lead Effect Factors, LEF_{HC} and LEF_{CO}

When the lead level of the fuel used for mileage accumulation is different from .03 grams per gallon, adjustments must be made to account for the difference. All corrections will be made to a final lead level of .03 gpg. Unless better data is made available during the hearings, the lead adjustment factors will be based on data supplied to EPA in the March 1973 suspension request update submitted by Ford Motor Company. These data indicate that lead levels higher than .06 cause more rapid poisoning of the catalyst with subsequent increases in the 4000 mile emission levels while levels less than .03 result in lower 4000 mile emissions. The loss in catalyst efficiency between 4000 miles and 50,000 miles, however, is apparently *less* severe with somewhat higher lead levels than with .03. At lead levels lower than .03 the loss in catalyst efficiency is apparently more severe for CO and less severe for HC. While this effect on DF may seem paradoxical on the surface it actually is not. The effect on DF should not be confused with the effect on emissions. The Ford data indicates that if two identical cars are run on two different lead levels the car with the higher lead level will have higher emission levels at every point between zero to 50,000 miles even though the DF for that car is lower. The rate of catalyst poisoning appears to be inversely proportional of the level of poisoning already experienced. It is the rate of poisoning between 4000 and 50,000 miles, not the level of poisoning, that affects DF. The rate of poisoning for the higher lead level case is lower between 4000 and 50,000 because the level of poisoning is higher at the 4000 mile point. Even though a catalyst run at a higher lead level may be less efficient at every point between zero and 50,000 miles its DF, between 4000 and 50,000 miles, could be lower.

The most obvious example of why this is true might be the case where one catalyst is subjected to .03 gpg lead and another catalyst is subject to one hundred times that level. The catalyst using .03 fuel might uniformly deteriorate from 90% to 60% efficiency in 50,000 miles while the catalyst using 3 gpg fuel might deteriorate from 90% to 0% in only 4000 miles. The DF for the 3 gpg catalyst could be 1.0 between 4000 and 50,000 miles even though it is completely poisoned and ineffective. The DF for the high lead level case is lower even though the emissions are higher. Unless better data becomes available, adjustments will be based on the data supplied by Ford.

Since the 0 to 4000 mile factor and the 4000 to 50,000 mile factor are always used in conjunction, a composite factor has been developed. This factor is different for HC and CO. This factor is derived from the table included and labeled "Lead Factor". To convert the extrapolated 50,000 mile emissions from a vehicle operated with a fuel lead level different from .03 gpg. enter a graph at the different lead levels and read the value of the lead effect factor. Multiply this factor by the uncorrected 50,000 mile emission value. The result is the corrected emission level for .03 gpg fuel.

The values of the lead factor are:

HC:

Pb=.003	1.5
Pb=.03	1.0
Pb=.05	.84

CO:

Pb=.003	1.35
Pb=.03	1.0
Pb=.05	.76

Construct a graph with lead level on the X axis and Lead Factor on the Y axis. Draw straight lines between each point in the table. Extrapolate the lines to 0.0 for sterile fuel.

These factors are not simply a 10% correction factor. Use of this methodology will increase the emission values at 50,000 miles by 32% for HC and 23% for CO, when converting from .01 gpg to .03 gpg for example.

Slip Factor, SF

Another adjustment applicable to 4000 mile levels may be some sort of slip factor. This adjustment would account for the differences between the componentry used on the current prototypes and that which could be used during certification. Unless a manfacturer can prove that a difference in emission control would be experienced with production design versions of his control system, this factor will be 1.0.

Mr. Preyer. You raised the question of maintenance, and certainly, during the init ailuse of catalytic converters there were some serious questions raised about the deterioration of thes econverters.

What do you feel the maintenance experience will be on these? Will they be effective for 50,000 miles?

Mr. Cole. Are you addressing the question to me?

Mr. Preyer. The whole panel.

Mr. Cole. Well, as long as the microphone is here, I will try to answer that. We have said publicly that we are designing our converters to go at least for the 50,000 miles and still meet the standard without replacement.

Now, there are more things to this system than simply the catalyst. It involves carburetion, ignition, valve timing and the exhaust gas recirculation system. We are talking about the complete system. With unleaded fuel, we say the maintenance is reduced, because we do not have the lead salts and the lead deposits that usually interfere with the efficiency of our emission control devices. And we expect to run sparkplugs for 50,000 miles; we expect to run our ignition system for 50,000 miles, and our carburetion systems for that length of time and still maintain the relatively good efficiency as far as the overall emissions and fuel economy are concerned.

Mr. PREYER. Do the rest of you feel that that is practical?

Mr. MISCH. I think it should be clarified that the difference in maintenance requirements is not associated with any benefits from the catalyst, except to the extent that a catalyst demands unleaded fuel, and the unleaded fuel does have the advantage of eliminating lead salt deposits.

Mr. TERRY. I have a couple of additional points I think should be made. One is, our tests show what happens after you run on a tank of unleaded gasoline, and then put in a tank of leaded gasoline—and run it through the catalyst, followed by lead-free gas again, our tests show there is some recovery.

Suppose you start out at 90-percent conversion efficiency. You might go down with one tank to 80 percent, and you might come back up to 85, but you would never get it all back, according to our tests. It is progressive. You lose conversion efficiency continuously as you use lead. You do come part way back, but you never get all the way back.

Now, as far as maintenance is concerned, there are a lot of things that can be done to improve and reduce maintenance costs. I am sure this committee has heard that one of the elements that we are talking about is the electronic ignition, as we call it, which is a point-free analysis shows that this does, indeed, reduce maintenance requirements over a 2-year period for the customer of up to $100 estimated. So this is one of the things that does reduce maintenance but is completely independent of the use of catalysts. I think that is an important point.

What we are most concerned about, as far as catalysts are concerned, is that, in order to get improved durability, driveability, and fuel economy characteristics, that we go back and retune our engines to something close to what they were before we had emission controls because that is what we were aiming at then. With these adjustments if the catalyst does fail, the emission level would be higher than it would be for the engine modification systems without catalysts that we are now putting on our cars.

In other words, we would be tuning for these other things, but detuning as far as the emissions control is concerned. And, if, indeed, it turns out that there is a high percentage of failure of catalysts in the field—and certainly, it is going to be very hard to monitor this kind of performance—if it turns out that there is a high incidence of loss of conversion efficiency by the catalysts, we could easily end up where the air would be dirtier than it was if we carried over the 1974 requirements.

Now, another point that should be made is the level that we are talking about. You see, the easy thing from an engineering point of view, is to say, put the catalyst on, because then you have a nice, low level of emissions and you do not have to worry about all of the other things that contribute to emissions. The catalyst cleans up your exhaust system, and takes away a lot of your problems. But, on the other hand, if the catalyst loses its conversion efficiency, you are not doing the job in the engine, where we have thought from the beginning we should be doing the job. We know from experience with our engine system that we can last and can maintain low emissions level. And so we feel that, while it is an easier way out from the standpoint of the initial design of the car and the initial testing and certifying of it, it may well not be—and we do not think it is—the best thing from the standpoint of the millions of cars that are going to be built and distributed and used by the public.

Mr. COLE. Could I make a point there, Sid, just a second?

Mr. TERRY. Sure.

Mr. COLE. I think we want to distinguish the difference between the systems that we are talking about. There is a distinct difference between our systems. And I do not want to take the time to give you a technical explanation of our system, except, when we talk about electronic ignition. We are talking about a new approach to electronic ignition, where we are able to spark a gap in a sparkplug up to eighty-thousandths, instead of up to the traditional thirty-five thousandths. We are able to impress across those points around 35,000 volts of electrical energy, and we are also sparking that gap three times as long as in the traditional system.

Now, this permits us to run one and a half, at least one and a half, air fuel ratios leaner than the traditional system. So that by running leaner, we are able to improve our fuel economy. At the same time, we can provide the O_2 or the oxygen in the system that the catalyst needs to convert CO and HC into CO_2 and water vapor. So, I think when you talk about a catalyst, you should take a look at the differences in the systems and how they have been designed to accomplish this entire requirement. And that is where we believe a part of the improvement in fuel economy has been developed with the General Motors system.

Mr. TERRY. Well, we feel we are the original exponents of the lean burner. This has been our approach from the beginning, and we certainly agree with Mr. Cole on that.

Mr. ROGERS. May I interrupt?

I am sorry. The full committee has issued a call.

If you gentlemen will bear with us, we hate to ask you to do this, but we will reconvene at 5 o'clock.

Now, while we are gone, if you do not mind, I would like for you to visit with the couple of young men from New York who have developed a device on the Matador——

Mr. COLE. We know them.

Mr. ROGERS. If you could talk to them a little bit, then I would like to get into some discussion of that a little later, if they could come up and talk to you while we are gone.

Mr. TERRY. I do not think we can talk to them as a group, can we?

Mr. ROGERS. Under the auspices of this committee, you could, under the eyes of the Government.

The committee recesses until 5 p.m.

[Whereupon, at 3:30 p.m., the subcommittee was recessed, to reconvene at 5 p.m. the same day.]

[The subcommittee reconvened at 5 p.m., Hon. Paul G. Rogers, presiding.]

Mr. ROGERS. The subcommittee will come to order.

We will continue the questioning. The members will be here presently.

Mr. Hudnut, do you have any questions at this time?

Mr. HUDNUT. Thank you, Mr. Chairman.

I would like to ask Mr. Cole a couple of questions. The first has to do with the statement that was attributed to you in an interview you had with the Associated Press relative to the amount of gasoline that could be saved per day if we were temporarily to suspend the present requirements and revert to the standards for the 1969 automobiles, and I was wondering if you could refresh my recollection on exactly what you said and expand on that a little bit.

Mr. COLE. Yes.

I want to make it clear that General Motors is not recommending that we take away the emission controls. We felt because we were asked what effect removal would have, that we owed some of the people in Government this information, and we provided this information.

In General Motors' case, if we would remove some of the control devices that we currently have on the 1970, 1971, 1972, 1973, and 1974 cars, we have estimated that it would save 5 percent of fuel economy on the 1970 cars, 2 percent on 1971, 5 percent on 1972, 6 percent on 1973, and 6 percent on the 1974 cars. Now, this, nationally, adds up to roughly 2,700,000,000 gallons of fuel on an annual basis, and this would be available if you could do this immediately. Then this total amount could be conserved.

Then we also calculated the effect on ambient air quality because of these changes in emissions from cars and we have this information. If you would like to have us enter it into the record, we would be happy to do it.

Mr. HUDNUT. If the Chairman thinks——

Mr. ROGERS. Without objection, it will be made a part of the record.

[The following information was received for the record:]

EFFECT OF RETROFIT ON AUTO EMISSIONS FOR 1970–74 CARS

The effect on air quality from a program to increase fuel economy by removing some emissions controls and retro-tuning engines can be determined from data indicating the changes in emissions from 1970–74 cars if such a program were imposed on them. Figure 3 indicates the increased hydrocarbon emissions and Figure 4 indicates the increased carbon monoxide emissions.

FIGURE 3

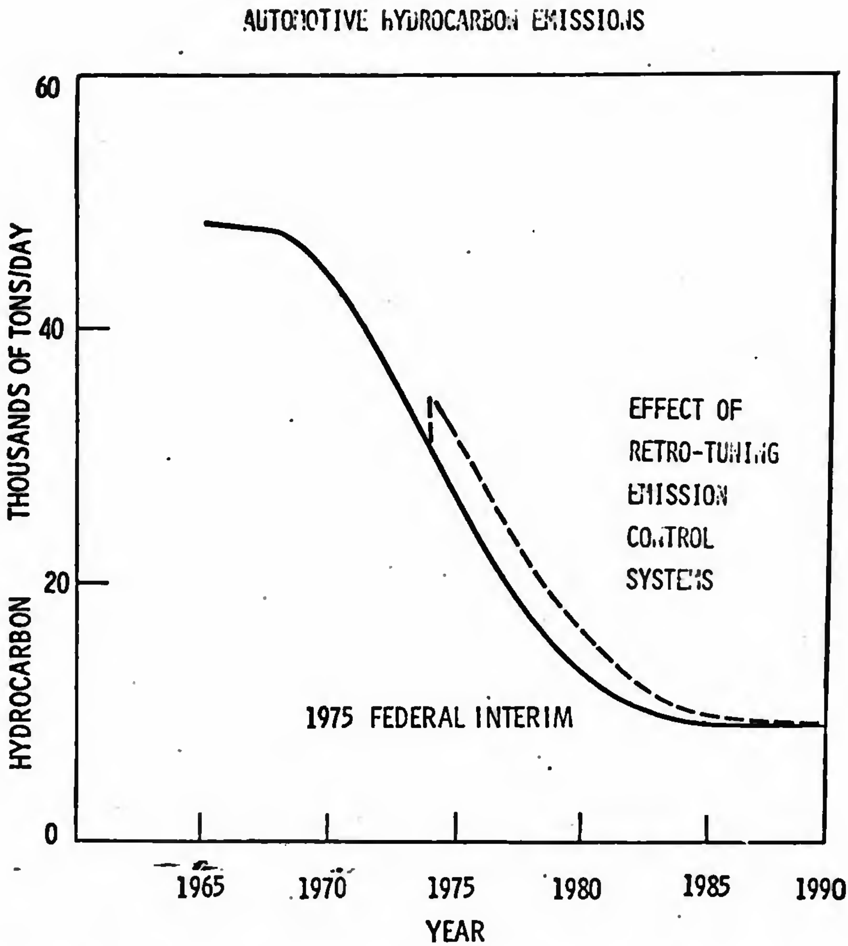


FIGURE 8.—*Projection of Nationwide Automotive Hydrocarbon Emissions with Retro-Tune Strategy*

(Solid line represents the trend of hydrocarbon emissions reduction if emission controls on 1970–1974 model cars are unchanged and all 1975 and later cars meet the 1975 interim standards. Broken line illustrates the trend of HC emissions reduction if retro-tuning is performed on all 1970–1974 cars and all 1975 and later model year cars meet 1975 federal interim standards.)

FIGURE 4

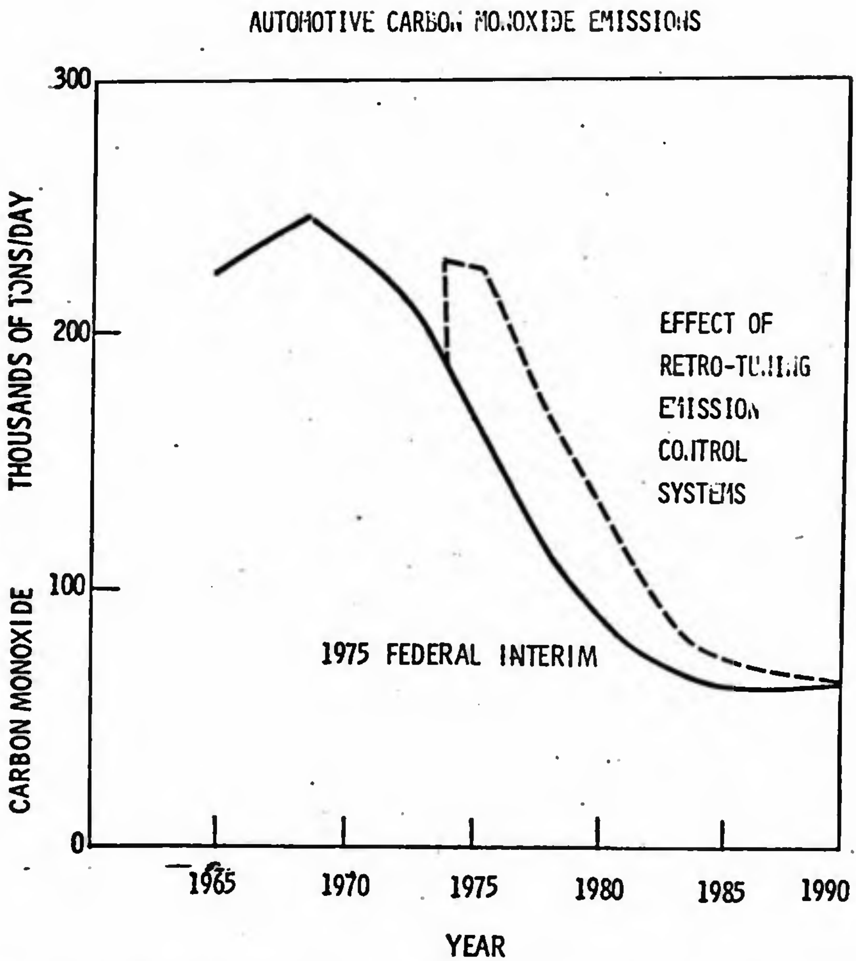


FIGURE 9.—*Projection of Nationwide Automotive Carbon Monoxide Emissions with Retro-Tune Strategy*

(Solid line represents the trend of carbon monoxide emissions reduction if emission controls on 1970–74 model cars are unchanged and all 1975 and later model cars meet 1975 interim standards.

Broken line illustrates the trend of CO emissions reduction if retro-tuning is performed on all 1970–74 model cars and all 1975 and later model year cars meet 1975 federal interim standards.)

Mr. HUDNUT. Thank you.

Mr. Chairman, I know you have many questions, so no further questions. That is fine, thank you.

Mr. ROGERS. Let me ask some questions until the other members arrive.

What about improving mile per gallon by a performance standard? What is the reaction of the industry to this?

Should this not be done?

If anyone commenting would just pass it around.

Mr. MISCH. We are talking about a fuel economy performance standard?

Mr. ROGERS. Yes.

Mr. MISCH. Well, our opinion is that there are several rather major problems with the establishment of performance standards that would accomplish the obvious desirable result, and at the same time not be so encumbering and so limiting upon our industry that we could fail to produce the vehicles that are necessary for a viable transportation system.

Now, we think that it is necessary that we have a generally accepted method of measuring and expressing fuel economy so it is understandable to the consumer. We do not have such a method today. Each of us has our own approach to testing, and over time we have determined that test which seems to correlate best with the fuel economy which our customers say they are getting with our vehicles. But as an industry we have no generally accepted standard.

We think there should be a standard developed that the industry and Government agencies could accept as an appropriate method of determining and expressing fuel ecenomy

Beyond that point we think that the marketplace provides adequate motivation and adequate incentive to the manufacturer to cause him to produce vehicles that are constantly better in improved fuel economy. We do not think that we would get the result that is desired by establishing some firm, inflexible fuel economy standard. As we know at times it is difficult to amend such a standard when it is wrong. A standard is not going to be as practical and as effective as the marketplace itself.

Mr. ROGERS. Mr. Cole?

Mr. COLE. Yes; I concur completely with Mr. Misch. I would like to add that the EPA has commissioned the Society of Automotive Engineers to try to develop a standard for measuring fuel economy that could be used universally and where you could make direct comparatives.

Herb, I understand that is underway, and there is some work being done, so I do not think we are trying to invent something new in this area. This is well underway and I completely concur with Ford's attitude toward the idea of setting some kind of a number of determining, predetermining what the mileage performance for gas should be.

Mr. ROGERS. Yes.

Mr. TERRY. I know you commented some on the bill in your testimony.

Mr. TERRY. Yes. Well, I think we should make clear from what these gentlemen have already said is that we all agree there should be a standard method of measuring fuel economy. Regardless of whether we have any performance standards on fuel economies, that is desirable so we can label and the labeling will be meaningful, and so that people will know that the different ratings for the different cars represent what they might expect to actually get if they were driving.

We do not have an acceptable method yet. We are working on it. Everybody agrees we should have it before we do anything.

Now, as far as the desirability for setting minimum standards for fuel economy for cars, this is an entirely different matter because, if we say there is only going to be one minimum standard, for example, a minimum standard that no car can have worse fuel economy than let us say 10 miles a gallon, just for want of a better figure, that automatically rules out——

Mr. ROGERS. We all want a better figure.

Mr. TERRY. Well, right.

Mr. ROGERS. Including you, I know. No; I understand.

Mr. TERRY. What that does is rule out a whole class of vehicles.

Mr. ROGERS. Yes.

Mr. TERRY. But if we say, let's have more than one standard, one for this kind of car and one for another kind of car, and then we get into a whole pyramid of minimum regulations, that involves the tolerances and how you are going to measure it including the assembly line testing and warrantee and all of the rest of the things that go with it.

Mr. COLE. Certification.

Mr. TERRY. It would involve a whole new set of paperwork and requirements that would equal or surpass what we now already have on the emissions. The problem is that these things are conflicting, and we get into a situation where we have got more and more regulations, more redtape and so on, all conflicting with each other to the point where you could be regulated to the point where you could not build cars, where you have the completely insoluble problem, just from the complication of all the interlocking regulations and redtape.

So we do not believe that minimum fuel economy standards are practical or workable as a means of reducing or improving the fuel economy of cars as a whole. We think it would be really an intolerable situation.

Mr. ROGERS. Thank you.

Dr. Carter, had you questioned?

Mr. CARTER. No, sir; I had not. I do thank you kindly.

I believe that you gentlemen in the past have stated that if we went to lead-free fuel, it would cause a loss of 1 million barrels of crude a day; is that correct?

Mr. TERRY. That was changed. We said 1 million gallons.

Mr. CARTER. Yes. Well, I thought—it is written 1 million barrels.

Mr. TERRY. That is right, and that is incorrect.

Mr. CARTER. One million gallons, but there would be an increased use.

Mr. TERRY. We figure it is about a 6- to 7-percent increase in the use of crude for a given number of miles traveled, everything else being equal, and the reason we figure that is because we are talking about going from a 95 to 96 octane car with the higher compression ratio that you can put in that car, comparing that to the 88.5 octane rating of a base pool, and on that kind of basis, counting the refining loss or the compression ratio loss, whichever way you want to take it, the total is going to be in the range of 6 to 7 percent.

Mr. CARTER. Six to 7 percent; yes, sir.

Do you have a method of removing sulphates with your catalytic converter?

Mr. TERRY. No, sir. I am afraid that sulphates are going to result from whatever sulphur there is in the gasoline, in the exhaust, some sulphates, regardless of whether or not you have a catalyst. It is just that with the catalyst you will have more sulphates in the exhaust than you would if you did not have a catalyst.

Mr. CARTER. Sulphur dioxide, if emitted, would become what on a misty day, that is, SO_2 if it is emitted from a catalytic converter.

Mr. TERRY. Well, that could be a health problem, yes. We do not know.

Mr. CARTER. What would the result be?

Mr. TERRY. Well, you could get the formation of sulfuric acid mists, which of course would be harmful to health.

Mr. CARTER. I certainly think it would be.

Thank you, Mr. Chairman.

I reserve the balance of my time.

Mr. ROGERS. All right.

Mr. Kyros?

Mr. KYROS. Thank you, Mr. Chairman.

Mr. Misch, there has been testimony on November 5 by Ford that it would manufacture all of its cars for 1975 for use with unleaded fuel; is that correct?

Mr. MISCH. That is correct; yes, sir.

Mr. KYROS. And that with certain cars, like your small car, your Pinto, could be used only with unleaded fuel, and that they would be manufactured without a catalyst; is that correct?

Mr. MISCH. That is correct.

Mr. KYROS. Would all your 1975 cars be designed to run with unleaded fuel?

Mr. MISCH. Yes. The reason for that is that there is an aid in meeting the hydrocarbon standards if we use unleaded fuel as compared to leaded fuel. To reach the 1.5 gram hydrocarbon requirement for the 49 State 1975 standard in the noncatalyst cars we have elected to take advantage of the hydrocarbon reduction we get with unleaded fuel.

Now, this decision, of course, must be determined well in advance, not only in production, but in advance of certifying for production. We must establish what fuel we are going to certify with, so we have already had to make that determination. Our certification tests for 1975 have started, and if we certify them on one fuel, that is the fuel that we have to recommend then to the consumer. So if we certify with unleaded fuel, then all of those vehicles will be equipped with a special filler neck that requires a special nozzle from the pump to use that fuel.

Mr. KYROS. All right.

What about the statement in the testimony from the gentleman from Chrysler Corp. that lead-free fuel has a given penalty in the loss of crude oil at the rate of 1 million barrels a day?

Mr. SYMINGTON. Gallons. He has written barrels, but he means gallons.

Mr. KYROS. Right.

Mr. MISCH. We have noted the statistics that have appeared in testimony by various oil companies and others relative to this loss in crude that is attributable to the manufacture of lead-free fuel. We said that we could see in our 1975 vehicles that use catalysts about a 3-percent improvement in fuel economy over 1974, but that that probably would be offset by losses due to yield per barrel crude, and we concede that. And it is for that reason that we made the point that in 1975 our Ford vehicles—if built to comply with 1974 carryover standards using leaded fuel—would have the same average fuel economy as they would if we utilized catalysts across the board and unleaded fuel.

Mr. KYROS. Now, what about this fact also appearing in the testimony by the gentleman from Chrysler, that only 45 percent of the Nation's gas stations will have lead-free fuel?

How does that jibe with your use in all of your 1975 cars of unleaded fuels?

Mr. MISCH. We have concern about the availability of lead-free gasoline. There is one thing about it; the catalyst vehicles, of course, must have unleaded fuel. They actually will operate improperly and the catalysts can be destroyed if they are fed leaded fuel consistently.

The noncatalyst cars will temporarily—for the period of time in which they are fueled with unleaded gasoline—build up some additional deposits. There is more of a buildup of the emission of hydrocarbons than we would normally anticipate, but we do think this heals again when we run it out with the unleaded fuel.

Mr. KYROS. So your cars would be unleaded, noncatalyst, and you want a 1974 carryover.

Mr. MISCH. Our cars, to meet the 1975 interim standards, would be a mixture of catalyst and noncatalyst but would operate on unleaded fuel. That is our plan. We are concerned because of the energy situation, and really the unknowns of what are we going to have, rationing or allocations or you name it——

Mr. KYROS. We will have everything.

Mr. MISCH. Whatever it is, it is going to be a confused situation for a while, and we are saying, "Let us not take the plunge to make an absolute requirement for unleaded fuel until this thing straightens out a little bit."

Mr. KYROS. Thank you, Mr. Misch.

Thank you, Mr. Chairman.

Mr. ROGERS. May I clear up one point there?

Now, when is the deadline for this decision to be made?

In other words, EPA says spring is a sufficient time.

Mr. MISCH. Well, if I understand EPA's testimony, I did not really read it verbatim, but if I understand it correctly, they said there is no need to take any action with regard to 1976 requirements until spring.

Mr. ROGERS. Yes, this is right, spring of 1974.

Mr. MISCH. Right. We take issue even with that. It is too late even for 1976. One of the reasons we are encouraging this committee to consider an amendment to the energy bill is because we really need an answer by the end of the year if at all possible. I heard in your full committee meeting, that you were talking about adjournment until late in January. If we have to wait until February or March, we will be too far down the road to take any reasonable action with regard to 1975 for certain, and we will really be late with respect to 1976.

That is the reason we are arguing for an early decision.

Mr. ROGERS. This is what I am wondering. Could you still take action on 1975?

Mr. MISCH. Yes, sir. We could take action on 1975 if it were one of two things. If it were a carryover of 1974 we could do it because many of our cars are already certified to those levels. It would have to be stipulated that the carryover standards would be maintained with the procedures and regulations that were used to certify to those standards in 1974. Everything would have to stay the same.

I will say that for Ford Motor Co., we would have one additional problem. We have some new cars coming out in 1975 that have never been tested to 1974 levels, and therefore never certified to 1974 levels. We would have to take on the certification task of those to a new 1974 level. They are at the moment being run to 1975 levels with catalysts or with unleaded fuel, so we would have that turnaround.

What we are saying today is that it is late. In certain instances on these new cars we might have to say that we are not going to make it by time of our normal production date.

Mr. ROGERS. What do you have to do for 1975?

Mr. MISCH. For 1975 we are in the process of carrying out our certification program right now. We have started.

Mr. ROGERS. In other words, you do not have to take any additional action now.

Mr. MISCH. If the final action was to establish the existing standards for 1975 models.

Mr. ROGERS. Was 1975?

Mr. MISCH. We would have no further action to take for 1975.

Mr. ROGERS. Yes.

Mr. MISCH. But we do need to know definitively what it is.

Mr. ROGERS. I understand.

Mr. MISCH. And I really believe that this is one point, if none other, of agreement. We need to know real quickly what is going to happen.

Mr. ROGERS. I think it would be well for all of you to go on record stating the time element.

As I understand it, all of your basic decisions have already been made and cranked in for 1975.

Mr. MISCH. That is correct.

Mr. ROGERS. Would that be true with Chrysler, so that you can move on 1975?

Mr. TERRY. What we are doing, we can move on 1975, but what we are doing with our 1975 certification is we are running both catalyst and noncatalyst in a number of different cars, parallel programs to—well, for two purposes, both to see if we can actually meet the 1975 emission levels, Federal interim emission levels without catalysts, even the 1975 levels, and also in case, of course, it is carried over, we could use those cars in the certification cars at the 1974 levels.

Mr. ROGERS. Of course. I understand.

Mr. MISCH. Mr. Chairman, there is one other point, and that is with regard to this timing, and maybe the other gentlemen can speak to this point, too, and that is the point I made that it is late for 1976 as well. If no action is taken by Congress, 1976 would require that we then meet a new standard of .41 hydrocarbons, 3.4 carbon monoxide, and 2 grams of oxides and nitrogen. I would like Mr. Cole to address this issue—I think we all agree if we take that step, there will be a further loss in fuel economy by each and every one of us.

Mr. ROGERS. For 1976.

Mr. MISCH. For 1976, and so time is wasting as to what we are supposed to be doing for 1976. This also makes it very urgent that Congress take action.

Mr. ROGERS. Yes; I understand that.

Mr. Cole, you may just like to comment, and then I will turn it over.

Mr. COLE. We certainly agree with both Ford and Chrysler, and I would like to straighten out one thing. If the 1974 standards that we have today prevail in place of 1975 interim standards, and that decision has to be made by a congressional recommendation or action, as I understand it, General Motors would use the 1974 system that we have now in production in 1974, and we would expect to continue roughly the loss in fuel economy that we have said we would gain if we used the catalytic converter for 1975, or the 13-percent differential. This is because we do not have time to work up new systems for 1975 certification. So we would have to rely pretty much on the technology that we have in place for 1974. That is about that position.

Now, the point——

Mr. ROGERS. So you would experience a fuel loss if you were required to do the 1974 standards in 1975.

Mr. COLE. That is right.

Now, we could elect to use our 1975 system even with the 1974 standard, and get the fuel economy gain that we have talked about, but then we would be at a competitive cost disadvantage in the marketplace. This is a business decision, and we are going to have to determine whether the gain of 13 percent in fuel economy has a sufficient competitive advantage to offset the cost increase of the 1975 system. That is a business decision.

Mr. ROGERS. Sure, I understand.

Mr. Heinz?

Mr. HEINZ. Yes; thank you, Mr. Chairman.

Mr. COLE. If I may interrupt, I would like to make one other point, if I may.

Mr. ROGERS. I did not mean to interrupt you.

Mr. COLE. I go further and say we do not have the technology today, with the catalyst or without, to meet the promulgated 1976 standard that is now on the book.

Mr. ROGERS. Which goes to the NO_x, mainly, I presume?

Mr. COLE. No. It goes to the .41 of hydrocarbons and 3.4 carbon monoxide, and the 2 NO_x, and we simply do not have that technology to accomplish that today. We have told the Senate committee that we simply would have to be out of business, because we could not certify our cars to that level for 50,000 miles.

Mr. MISCH. Mr. Chairman, we told the Senate committee the same thing, and I think we told your committee earlier this spring.

Mr. ROGERS. Thank you.

Mr. TERRY. We agree that we do not have the technology for 1976.

Mr. ROGERS. Thank you.

Mr. MISCH. Once again, it indicates why it is so urgent we get some action relative to 1976 as soon as possible.

Mr. COLE. If we do not get action, we are out of business.

Mr. ROGERS. Yes.

All right, Mr. Heinz.

Mr. HEINZ. Thank you, Mr. Chairman.

Mr. Misch, I was interested in something you said with respect to your 1975 models. You said that some of your cars would use catalysts, others would not?

Mr. MISCH. That is correct.

Mr. HEINZ. You also said that all would use unleaded gasoline. Is that correct?

Mr. MISCH. That is correct.

Mr. HEINZ. Why is it that you must use, or choose to use, unleaded gasoline in noncatalyst cars?

Mr. MISCH. There are two reasons. One of the reasons is, in order to meet the more stringent hydrocarbon standard for 1975—the 1.5 grams per mile of hydrocarbon. We get an advantage in using unleaded fuel, because of the difference in the cylinder deposits between leaded and unleaded fuels. The unleaded fuel allows us to meet the hydrocarbon standard on some cars where we would not otherwise be able to comfortably meet it. That is one reason.

The other reason is related to the maintenance requirements during certification, and of course, in the field. With leaded fuel, because of deposits, we would have to have warning devices with regard to certain portions of the system in order to indicate that they were malfunctioning, and, therefore, that they required maintenance. We do not have such warning devices invented, as a matter of fact. With unleaded fuel, the EGR systems will operate longer without maintenance.

Mr. HEINZ. You have answered my question. Let me ask you another question on another subject.

On page 2 of your testimony, you stated that 1975 fuel economy with catalysts is only 3 percent better than the 1974 models. What was the sales weighting assumption with respect to that statement?

Did you assume a constant mix?

Mr. MISCH. It is a constant mix all the way through.

Mr. HEINZ. Therefore, if you achieved a larger proportion of sale with smaller cars, that 3 percent might, in fact, be a better number and might increase? Is that correct?

Mr. MISCH. Yes. And I want to point this out very clearly. I have tried, in the data that I have used, to speak only to the influence that emission control has on fuel economy. I have tried to separate everything else out and say that is a separate issue. The issue before this committee is the effect on energy due to emission control, so let me make sure——

Mr. HEINZ. I understand.

I have very little time, so I have to move along quite rapidly.

Yesterday—and I will get to Chrysler and GM if I have time, with some relative questions—yesterday, the API testified that in 1975 they would experience an approximately 16,000-barrel-a-day penalty to produce all of the unleaded gasoline that is required for your purposes and the purposes of the auto industry. That is equivalent—and they agreed with this calculation—that it is less than one-quarter of 1 percent, is the equivalent of 6 million barrels for a year. It is—6 million barrels is also the equivalent of a total of 8 hours' supply.

Do you agree or disagree with their calculation?

Mr. MISCH. I cannot either agree or disagree. What we have used is kind of an average of those reports that have been presented in various testimony on the subject.

I can understand why there might be confusion on this point. It depends upon what refinery you are considering; what equipment there is in that refinery; and its capability for making unleaded fuels of the higher octane variety.

Now, you should assume that almost every refinery throughout the country is going to have to do its share in making some of the unleaded fuel, rather than just assigning the unleaded fuel production to those few that have the equipment, I think if you assume that the task is spread out throughout the country, that is when you get the higher percentage of loss.

Mr. HEINZ. Very good.

Thank you very much, Mr. Misch.

Mr. Terry, in the remaining time I have a couple of questions that relate to you, as well as the rest of the auto industry.

What percentage of automobiles, Chrysler products, now in use really require premium fuel?

Mr. TERRY. None of the cars we are building today require premium fuel.

Mr. HEINZ. I understand that. I meant to say in use today.

Mr. TERRY. I cannot give you a very good figure on that. We have not calculated it recently, but it would be—I would say somewhere between, maybe, 15 and 25 percent, something like that. It would depend on how many—I really should not try to answer.

Mr. HEINZ. In your statement, you talked a great deal about the petroleum requirements of the various technologies.

Do you also happen to have information as to what the percentage of total sales by the oil companies is with respect to premium fuel these days?

Mr. TERRY. No, sir, I do not have those figures.

Mr. HEINZ. I neglected, I have to confess, to ask them that yesterday, and I thought I would try you.

Taking one of your cars today that is designed to use 91 octane fuel, let us say leaded 91 octane fuel, is there any kind of a mileage benefit if a consumer, a driver of your car, puts in a high octane, 98 octane, fuel?

Do you get any mileage benefits?

Mr. TERRY. No.

Mr. HEINZ. No.

Mr. TERRY. And perhaps that will bring——

Mr. HEINZ. That is fine.

And the second question is, do you suppose there are any significant number of people who drive automobiles who unnecessarily use premium fuel?

Mr. TERRY. Yes, I believe there is.

Mr. HEINZ. Very good.

One last question, and this will be my last question, because I see the chairman wielding his gavel threateningly.

I believe you did correct, on page 2, line 6, of your testimony, the fact that you were talking about 1 million gallons a day rather than barrels?

Mr. TERRY. Yes.

Mr. HEINZ. Which is the equivalent of 20,000—roughly the equivalent of 20,000 barrels a day, which is, roughly, in the range of what the API testified yesterday to, which was 16,000 barrels. So I think you two are generally consistent.

Mr. TERRY. That is correct.

Mr. HEINZ. Again, it is around the range of one-quarter of 1 percent.

Mr. TERRY. That would be at the end of 1975. And if we continue to use lead-free gas, and more and more cars get on the road that required it, that number would go up.

Mr. HEINZ. Very good.

I thank you very much.

Mr. COLE. Could I respond to the question that you directed to Chrysler?

I think we have the data that you are talking about. The peak consumption of premium fuel represented in—it was in 1970—represented around 42.6 percent of the total sales of gasoline. In 1973, we forecast that figure to be 32 percent in 1975, to be 19 percent. And that is the position we took on the octane numbers that are available to make premium fuel are in excess of the octane numbers that we need for the 91, so those would be available to up grade the pools to the 91 level.

Mr. HEINZ. Mr. Cole, what percentage of GM products do you suppose will be on the road that will require high octane premium fuel in 1975?

Mr. COLE. Probably around 15 to 18 percent. This is a forecast, and how many are taken out of the population depending upon the energy shortage and one thing or another, it could—you see, those cars that require premium fuel are generally the more expensive, larger cars, and those could suffer some attrition.

Could I back up a bit? Dr. Boditch suggests that we correct the testimony I just gave to you. The premium fuel that was needed in 1970 was 32.3 percent. What was actually sold in 1970 was 42.6 percent, so there was a disparity between the 32.3 percent and the 42.6 percent, and that the petroleum industry was actually selling more premium that was actually needed to satisfy the cars.

Mr. HEINZ. They were selling roughly 27 percent more premium fuel than was actually required?

Mr. COLE. And we have contended if they would take those octane numbers and put them where they are needed, there would be plenty of 91 unleaded fuel.

Mr. HEINZ. All right.

I think my time has expired several times over.

Mr. SATTERFIELD [presiding]. Mr. Symington.

Mr. SYMINGTON. I thank the chairman.

Mr. Cole, you concluded your statement by saying that you want to work with us to achieve the goal we are all seeking, "elimination of the automobile, as an element in the Nation's"——

Mr. COLE. No.

Mr. SYMINGTON. I thought you would like to clarify that.

Mr. COLE. No, we are not working toward the elimination of the automobile. What we are talking about is eliminating the automobile as a concern as far as pollution is concerned, and that is our objective. I think we all concur on that, I am quite sure.

Mr. MISCH. Well, certainly not the former.

Mr. SYMINGTON. In that connection, with respect to the pollution problem, Russell Train, EPA Administrator, said on November 15 that you had suggested that we save gasoline by removing all of the emission control systems from 1970 to 1974 cars.

Was he accurate in making that observation?

Mr. COLE. We were asked how much energy could be saved if—and particularly, we were talking about General Motors cars—we could revert back to the emission control levels of 1969. And so in answer, we said if the entire population of those cars could be shifted over immediately—and these would be rather minor adjustments—that there could be a saving of 2.7 billion gallons of gasoline annually.

And we also gave him the information on the air effect of these 10 most highly stressed cities from air quality point of view.

Mr. SYMINGTON. As an engineer, I could not get between you on those questions of the difficulty of retrofitting the cars. But he claimed in his statement that the emission control system was an integral part of the modern automobile, not an add-on device that could easily be disconnected. And I take it you disagree with this?

Mr. COLE. Well—and I want to say this again, that General Motors did not recommend that this be done. We said, if energy is a greater concern than ambient air quality, this could be done, and it would have to be determined by Government.

And I have the amount on the retrofitting. If we retrofit a 1970, with minor changes, by advancing the spark, which is a distributor adjustment and disconnecting what we call transmission control spark and modifying the exhaust gas recirculation system, a 5-percent fuel saving was estimated for 1970; 1971 was 2 percent; 1972, 5 percent; 1973, 6 percent; and 1974, 6 percent.

Now, we put that into the record. We thought if there was a real issue on the energy, Congress may elect to postpone the need for the ambient air quality in light of the energy situation. However, this would be an option that only Congress possibly could take.

Mr. SYMINGTON. I am sure it is an option that will not be taken, but the main thing is that it does not seem to me that there is any clear agreement between EPA and General Motors on the feasibility of taking a step of that kind.

Train actually goes on to say that those changes could not be made without reengineering, rebuilding, the entire car.

Mr. COLE. That is not correct. What I have said here can be done by most any mechanic or in the home workshop.

Mr. SYMINGTON. Then he goes on to say that attempts to defeat the emission control devices in this way would result in poorer gas mileage, that their experiment showed that. That does not conform with your findings?

Mr. COLE. I am sorry to say it does not.

Mr. SYMINGTON. One of the difficult things that we face here, is that we have to confess that we are lay persons in the effort to assess the competence and the integrity of all of the testimony we receive, and we want to believe everybody, but it is a little difficult when they disagree.

Would you like to comment on that?

Mr. MISCH. Yes, Mr. Symington, I would, to this extent: I think the reason we are here as engineers is to do our level best to tell you the facts as professional people. Frankly, I do not see how EPA could possibly be in as good a position as we are to give you facts relative to this particular issue.

I have to agree with Mr. Cole. We do not support this kind of an action, insofar as the vehicles in the field. We do not support that kind of a retrofit. We are not opting for it as being the sort of tradeoff that is appropriate. If you gentlemen, sitting in your other committees and concerned about energy, say "Yes, it is appropriate," then we will establish the priorities to implement it. We are here to tell you as engineers it can be done.

Mr. SYMINGTON. While I have you there, Mr. Misch, I want to say how sorry I am to hear that Ford is closing its plant in the St. Louis area.

Mr. MISCH. Well, join the group. We hope to have engines and be back in production as soon as possible.

Mr. SYMINGTON. If I have time, Mr. Chairman, for a question that I think the Chair is interested in, there has been——

Mr. ROGERS. Yes, go ahead, Mr. Symington.

Mr. SYMINGTON. One more question; that is it.

Mr. ROGERS. Then you can have the second go round.

Mr. SYMINGTON. That is good; thank you, Mr. Chairman.

We understand that there is a proportional exhaust gas recycle that is said to present a 5-percent fuel economy EGR, and I am addressing this to the panel, whether or not there is information among you as to whether this device is ready for production and what it would cost and that sort of thing.

Mr. MISCH. Well, I will start. I will say that in the material that I gave as part of my statement, it shows the projections of what we could assume we could do in fuel economy. We show a continuing improvement. Part of that improvement is due to such things as more sophisticated tailoring of the way in which exhaust gas recirculation is controlled and the way spark ignition is handled. Exhaust gas recirculation is just one of the items.

Now, EGR has to be proportional to something. The term "proportional EGR" has kind of gotten away from us.

It is awful hard for you not to be proportional to something, and it is a question as to what kind of control you use to recirculate the exhaust gas. There are all kinds of such controls. Mr. Cole will probably tell you that in some of their submissions to EPA they have talked about proportionality to, I think, back pressure.

Mr. COLE. We are already using what you are talking about.

Mr. MISCH. And we have other types of proportionality which sense the amount of air that is being injected into the exhaust system and so forth.

There is no 5-percent plum ready to be picked that we are just being stubborn and will not take.

Mr. SYMINGTON. I thank the Chairman.

Mr. ROGERS. Mr. Hastings.

Mr. HASTINGS. Thank you, Mr. Chairman. I will try to be brief.

If I understood, you are all here——

Mr. ROGERS. That is welcome news.

Mr. HASTINGS. I beg your pardon?

Mr. ROGERS. That is welcome news.

Mr. HASTINGS. If I am, I will be the first one.

Mr. ROGERS. You have the full 5 minutes.

Mr. HASTINGS. You say you are all here as engineers trying to help us solve a problem. I think that is essentially the thought. And yet, I want to get this into perspective. GM, you would like to go to the 1975 standards and hold them in place for 1976–77; is that correct?

Mr. COLE. That is correct.

Mr. HASTINGS. Ford, what would you like to do?

Mr. MISCH. We would like to see the 1974 standards carried over for a couple of years.

Mr. HASTINGS. And Chrysler, what would you like to do?

Mr. TERRY. We would like to see the 1974 standards carried over for 2 additional years.

Mr. HASTINGS. You do not want to go back to 1970 then?

Mr. TERRY. No, sir.

Mr. HASTINGS. Then I have a difficult time trying to resolve in my mind whether we are really talking about the difference in standards or what is good for GM, Ford, or Chrysler, or whether we are really talking about catalytic converters, because that seems to be in the end the real question that we are faced with here.

If we go to 1975 standards, then we are going to go to catalytic converters. I know that GM is prepared to go; of course, I have heard your testimony. Ford, you say partially; and Chrysler, I am not sure.

Mr. TERRY. We are prepared to go to catalytic converters in everything if we need to. We are not going to put catalytic converters on any more cars than we have to, depending on what emission levels we can meet with our certification fleet.

Mr. HASTINGS. You have the technology ready to go with catalytic converters, however?

Mr. TERRY. Oh, yes. We could put catalytic converters on all cars.

Mr. HASTINGS. In other words, if we do go into the 1975 standards, you will be in that position to proceed?

Mr. TERRY. We may not elect to do so, because we think we can plan to——

Mr. HASTINGS. Well, however, you can meet the standards?

Mr. TERRY. Yes, sir.

Mr. HASTINGS. It is a general understanding that a large number of cars are going to have to use catalytic converters unless you have other technology.

And the other question is, of course, the impact on the refinery process of gasoline, the unleaded versus leaded. And we hear a great deal of discrepancy both from the auto industry and, of course, the petroleum industry.

I understand that General Motors is going to go to an unleaded with catalytic converters.

Mr. COLE. With or without. We are in the same position that Ford is on this.

Mr. HASTINGS. And Ford, you are also advocating; so that your question or your theory on nonleaded gasoline is what, Mr. Terry?

Mr. TERRY. Well, we do not plan—we are not going to use unleaded gas if we do not have a catalyst on the car. We are going to continue to allow those cars to use leaded gasoline.

Mr. HASTINGS. And therefore, it would appear that there is going to have to be unleaded gas whether we have converters or not on General Motors and Ford products, because both say with or without you are going to go to an unleaded gas, is that correct?

Mr. COLE. That is right.

Mr. MISCH. Unless you carry over the 1974 standards.

Mr. HASTINGS. Well, all right; but presumably we do not. Say we do not take any action, as EPA suggests or the administration, to carry out the 1975, which you agree with and the other two do not.

But the question remains we are still going to have to have some unleaded gas, whether we go to catalytic converters and therefore the 1975 standards or the 1974. Is that unleaded gas available in the marketplace?

Mr. COLE. We have been assured by the petroleum industry that there will be adequate unleaded fuel available. I have had two meetings with the principals of all of the major oil companies reviewing the position on fuel, not only the unleaded characteristics, but phosphorous content, sulfur content, volatility, and other characteristics of the fuel. And we have been assured that with the sulfur content remaining where it is, the volatility remaining where it is, phosphorous eliminated because that is another additive, and with the 0.03 grams per gallon as the average and 0.05 maximum, we will have all of the unleaded fuel that we need, not only in the United States but Canada and Mexico as well.

Mr. HASTINGS. All right then.

Within the limited time—and I am going to keep to my 5 minutes, Mr. Chairman. I have got figures that show me certain segments of the petroleum industry, say it is going to cost $4 billion to convert their refineries to production of enough unleaded gas to satisfy the needs of industry. EPA testified it was $100 million.

Can anybody shed any light on that?

Mr. COLE. You have got to be concerned whether you are talking about total conversion of all of the fuel or whether you are talking about only that fuel that is needed to satisfy the cars that are in the marketplace with the catalytic requirement or the unleaded requirement.

Mr. TERRY. We agree with that. I think this is one point they could clarify further. When we talk about a total loss of the 6 percent that you are going to lose in capacity to produce gasoline, we are talking about a total conversion of all cars on the road to lead-free gas, assuming this continues.

Now, we think it is important to look at the long range.

Mr. HASTINGS. Not just prospective, then—you are talking about all cars on the road?

Mr. TERRY. Yes. It would take some time to lose the 60-percent capacity. At the end of 1975 only about a tenth of the cars on the road will have been produced in 1975, and only some 70 or 80 percent of these cars will have catalysts, and so you will not need as much lead-free gas in 1975 as you will later on.

Mr. HASTINGS. All right.

I thank the gentlemen.

Mr. HEINEN. However, we have to make one more point here, and that is that the distribution centers would have to be converted, and that would be a one-time deal, and it had better be converted in 1975, or you are going to wind up in the middle of Kansas or in the center of Mexico with no unleaded fuel in sight.

So that is a one-time expenditure, and it has to be in 1975.

Mr. HASTINGS. How about the western part of New York?

Mr. HEINEN. Well, that is probably just as bad.

Mr. COLE. Well, I might add to that, we have reviewed this with the refining industry. Most of the distribution systems that are in place around the United States are capable of handling unleaded fuel today. There are just a few exceptions where they are on a two-fuel system; like Union Oil on the west coast, they are on a two-pump system. And I believe their plan—and I should not be speaking for them—is to upgrade the unleaded fuel to the 94 requirement, so they still can remain on a two-pump system.

Mr. ROGERS. I might say that when the oil companies testified yesterday, they stated that they had already done the conversion necessary to produce unleaded fuel. Now they are able to begin production.

Mr. TERRY. Again, that is for 1975, because it is not going to be that big a deal in 1975, although it is a start and an expensive start, and a step that will be hard to back away from. They are talking about what they can do for 1975 on the assumption this will not continue.

Mr. ROGERS. Well, they said in the middle of 1974 they would have this around May of 1974.

Mr. TERRY. Yes, but if catalysts continue in cars, they will have to continue to convert refinery capacity and then spend a lot more money down the road as more and more cars on the road require catalysts.

Mr. COLE. For example, Shell in Canada has 1,400 of its stations out of 5,000 that are currently dispensing unleaded fuel today.

Mr. ROGERS. Well, does not Amoco presently do this in this country?

Mr. TERRY. Yes.

Mr. ROGERS. Thank you.

Dr. Roy.

Mr. ROY. Thank you, Mr. Chairman.

I appreciate the gentleman's concern about ending up in the center of Kansas, but I might add that that is a pretty good place to end up.

Mr. HEINEN. It is not bad. I agree with you.

Mr. ROY. The goal that we are all trying to reach, of course, is part of the primary ambient air standards promulgated by EPA. May I ask you gentlemen, do you agree or disagree or have no opinion on these air standards?

Mr. COLE. Well, I have an opinion. We have no real evidence that there is accurate information on health effects of any standard for the moment; and we have suggested from time to time that Congress petition some competent outside body such as the National Academy of Sciences to make a long-range study, and not just a study that is going to be concluded next August 1974, because this will only be a summation of all of the information that is currently in the literature.

This is one of the reasons we have recommended that these standards which will improve the ambient air quality over time be held at the levels that we are talking about for a 3-year period to permit some of these studies to be conducted. And this cannot be done in a hurry. There is just no way you can do it in a hurry. So we question the health effect needs of some of the standards that have already been issued.

Mr. MISCH. I think our position has been that we do not have the data to either confirm or refute the necessity for these ambient air quality standards. We also have pointed out repeatedly the cost from an energy standpoint, and gross national product standpoint, of an "overkill" if the standards are not necessary. So we, too, have encouraged a continued look at these standards to make certain that they are necessary; and, second, that the portion of "rollback" which is required to accomplish those standards that is assigned to the automobile is accurately determined.

Mr. TERRY. Well, I think that is the important point. We do not know really about whether the primary standards are more stringent than they need to be or not. But with questioning that, we do have a lot of data and a lot of work has been done by other people that indicate that what has already been done on the cars and what will be done through 1974 will be enough to achieve the primary air quality standards in cities all over the country without going further as new cars replace old cars.

So we are not questioning the primary air quality standards as much as we are questioning the emissions standards that are now written into the books that are supposed to be necessary to, as they say, roll back the air quality.

We are saying the data supports our contention that we do not need motor vehicle emissions standards more rigorous than the 1974 standards.

Mr. ROY. Are any of your companies making any expenditures to determine the correctness or incorrectness of the primary air standards, quality air standards?

Mr. TERRY. We have commissioned Yale Medical School—that is Chrysler has commissioned Yale Medical School to make a study. This was done back in August before there was any action by Congress on this point. One of the principal things that we want them to look at and determine from what can they find out is what primary air quality standards are required to protect health. That study should be done in less than a year. I believe it is to be done by next July. There is a preliminary report already out—I believe it has been sent to Members of Congress—showing what they plan to do and how they plan to go about it. We think it will help to shed some light on this question.

Mr. ROY. Then, Mr. Terry, you disagree with Mr. Cole as to the length of time that is necessary to determine the correctness or incorrectness?

Mr. TERRY. Well, I think there is a lot more than the scientific studies that are going to be necessary. First, Congressman Roy, I believe that there is a lot of data already in the literature that has been uncovered that will show if it is studied, where the air quality standards might need to be. This does not mean there might not need to be a lot more data. More research would be valuable. But I think there is considerable data in the literature right now, and we think

Yale will supplement it in this time so that they will be able to come up with some meaningful conclusions in that time.

Mr. ROY. Do you anticipate that they may disagree then with the National Academy of Science?

Mr. TERRY. Well, the National Academy of Science has not really committed themselves on the need for the primary air quality standards as such to this point. As I say, we did not intend to commission Yale to get into any kind of conflict situation with the National Academy. We do not think that they will. We are simply saying that we have a directed study by a team that has worked together before, to include all of the aspects of air pollution control, including the health effects, which requires the doctors, the economists, and others, to talk about tradeoffs. And there is a lot of public health-public benefit philosophy that has to be woven into the decisions as to what kind of air pollution control we really need.

For example, on the question of carbon monoxide, the doctors themselves, who know the most about this, have been quoted—and I think misunderstood in some cases—that there may be no level of carbon monoxide below which there would be no perceptible health effects. What they really meant to say was that carbon monoxide can be likened to a load on the human system. There is always a certain percentage of carboxy hemoglobin level in the blood which shows how much carbon monoxide exposure that person has had.

Now, for example, the kind of levels we are talking about in the air are equivalent, let us say, the equivalent to a 3-percent carboxy hemoglobin level in the blood. And the level that EPA is talking about is keeping levels below 2½ percent. Five percent to 10 or 12 percent is not unusual in smokers.

The doctor that said there may be no level below which there might not be a perceptible effect went on to say some carbon monoxide is always going to be a load, to a certain extent, on the system. For instance, let us say 1 eprcent of carboxy hemoglobin is analogous to 1,000 feet of altitude, or a 3-percent load is analogous to eating a heavy meal.

And so if you say well, OK, can we afford to let the load on the human system go up 1 or 2 percent, that is really the kind of thing that we are talking about, so that we need some philosophy in this thing. And this is what we hope to get out of our Yale medical report.

Mr. HEINEN. Mr. Roy, may I just make one comment, because I was there when it was set up, the protocols were set up. What we told them is we are not sure about health effects. We want to know something about them. It is your show, which I think is the honest, scientific way to do it.

We were very active in the translation to emissions standards, but as to the health, we look for help.

Mr. ROY. We get varying reports as to how much money has been spent by each of the three major auto companies—if American Motors will forgive me—on achieving the technology necessary to meet the EPA standards for 1975–76 and thereafter.

Is this public information?

Mr. TERRY. Yes, sir.

Mr. ROY. Would you gentlemen like to give me this information on how much General Motors has spent to achieve this technology?

Mr. COLE. Yes; we have it all spelled out here, and it goes over a period of time. For vehicle emissions alone in 1967 we spent $51 million, and in 1973 we are forecasting $351 million. From 1961 to 1973 we spent $1 billion in this area; and we expect to spend an additional $1 billion going from 1974 to 1976. As far as tools and equipment for 1975, we are current committed for roughly three-quarters of a billion dollars worth of equipment today to meet the 1975 interim standards. And that has nothing to do with GM pushing for 1974 or 1975. It is not because we have any commitment. If Congress elects to trade off the fuel economy for lower emission controls in the 1975 interim, General Motors would go right along with it, despite the commitments of three-quarters of a billion dollars.

Mr. MISCH. I do not have all of the figures with me over time, but just as a stake in the ground in comparison to Mr. Cole, we will spend $320 million in this calendar year on emission related expenditures. I think for that particular thing—Mr. Cole said $350 million, something like that—so we are in the same ball park. It almost scares me. It sounds like on the basis of share of market we are spending too much.

[The following information was received from Ford Motor Co.:]

TOTAL EMISSION EXPENDITURES

[In millions of dollars]

	1967	1968	1969	1970	1971	1972[1]	1973
Research and engineering:							
Research and engineering	$9	$11	$14	$21	$35	$59	$98
Certification	1	1	2	2	9	12	24
Testing data analysis and communications	(2)	1	1	2	3	5	5
Alternate power sources	5	5	7	8	13	20	30
Total, variable	15	18	24	33	60	96	157
Support cost	8	8	12	19	30	36	57
Total, research and engineering	23	26	36	52	90	132	214
Cumulative total, research and engineering	23	49	85	137	227	359	573
Other emission expenditures:							
Tooling	8	7	10	5	11	15	55
Facilities	16	3	4	9	27	15	39
Launching	4		3	1	4	3	11
Total, other	28	10	17	15	42	33	105
Total, expenditures	51	36	53	67	132	165	319
Cumulative total, emission control expenditures	51	87	140	207	230	504	823
Research and engineering equivalent headcount generel average:							
Variable	755	883	1,159	1,501	2,345	3,160	5,381
Support	315	318	389	517	752	881	1,139
Total, equivalent headcount[3]	1,070	1,201	1,548	2,018	3,097	4,041	6,520

[1] Excludes 1973 model recertification.
[2] Less than 500,000.
[3] Includes salaried, hourly, outside agency end overtime.

Reference: June 18, 1973, Request for Suspension of 1976 Motor Vehicle Exhaust Emissions Standards submitted to EPA (updated).

Mr. COLE. We have 4,200 people committed to this program currently.

Mr. TERRY. Well, these things—I do not remember the exact number of millions of dollars that we are spending for emission control alone; but the figure that I have been using in discussing the effect of regulations and expense on regulations is now approaching 40 percent of our total research and development budget; that is everything that we do in research and development.

And this, of course, does not include the millions of dollars that we are spending on equipment to measure emissions and production, which is another matter again. We have not been adding those two together until recently. We can submit more information for the record.

Mr. ROGERS. Yes, I think for the record.

Mr. ROY. With the chairman's permission, I would appreciate that.

Mr. ROGERS. Certainly.

[The following information was received from Chrysler Corp. for the record:]

SUMMARY, EMISSION CONTROL RESOURCES, CALENDAR YEARS 1967 THROUGH 1976

[Dollar amounts in millions]

Calendar year	Total dollar resources (emissions)[1]	Total dollar resources (all R. & D.)	Professional technical man-years	Light-duty vehicle sales
1967	$2.9	$75.7	140	$3,790
1968	4.4	83.9	172	4,642
1969	6.6	95.1	260	4,189
1970	9.0	81.5	329	4,041
1971	14.4	90.4	434	4,640
1972	19.8	124.0	705	5,296
1973	46.5	150.0	1,075	5,720
1974	49.8	174.8	1,290	6,544
1975	(2)	(2)	(2)	7,274
1976	(2)	(2)	(2)	8,007

[1] These figures have been prepared by using analysis techniques and are not taken from official books of records.
[2] Estimates not available until more is known about Government emissions and safety standards beyond calendar year 1975.

Note: Design office R. & D. not included in above.

Mr. ROY. I thank you for your testimony. I might say if it were 3½ years ago and I had not been a Member of Congress, I probably would not have been able to figure out how many zeroes to add to all of those numbers.

Mr. ROGERS. Mr. Nelsen?

Mr. NELSEN. Thank you, Mr. Chairman.

Some of us, including myself, when we sat in conference, took the view that we were setting our targets at too early a date, which would not permit the industry to develop the engineering to reach the goal that we set up. Now, then, it would appear that had you had a little more elbow room in reaching this goal, it might have avoided a model of automobile that uses more fuel, and if you had had a little more time, you could have reached the goal that we set up.

Is that an accurate appraisal at this time?

Mr. TERRY. I think it is.

I would like to say one thing that has not been said about fuel economy. We find at least in the emissions control work that we have done, that almost all of our fuel economy loss has been due to control of oxides of nitrogen, and this is kind of fundamental. With both hydrocarbons and carbon monoxide, the better job you do of burning the fuel in the cylinder, the lower the emissions of hydrocarbons and carbon monoxide, because both of them burn under oxygen.

On the other hand, oxides of nitrogen are formed as a result of the two principal elements of the air, oxygen and nitrogen, which combine together just at high temperature. All it takes is high temperature to make oxygen and nitrogen combine to form oxides of nitrogen, and it happens as engineers and scientists understand readily, that the higher temperature you have in a heat machine, the more efficient that machine gets, but really what we have to do to achieve oxides of nitrogen control is to lower the maximum temperature of combustion some way or somehow, and in the process, we lower the efficiency of our machine.

Our fuel economy penalties have been almost entirely due, so far, to control of oxides of nitrogen, not hydrocarbons and carbon monoxide. If, in the future, we have to go to more stringent controls of oxides of nitrogen, that again will be where our principal problem in control of fuel economy will lie.

Mr. NELSEN. Of course, in reaching that goal, obviously a little more time would not have hurt.

Mr. TERRY. That is true.

Mr. NELSEN. What I am trying to say is we in the Congress write laws and make demands and then our enforcement agencies have to follow the criteria we set up.

Another question. We would like to think that persons that would be put in control of a program will give industry a chance to present their position, their achievements, and what goal they can reach comfortably.

Now, I am wondering if EPA has had the door open so you can have communications to tell them what your problems are, what you are able to do, and what time you would need.

Now, for example, it has been called to my attention that the measuring of emissions of each individual auto produced compared to taking an average, is quite an unfair way of measuring. Mr. Cole, you mentioned that to me.

I wonder if you would, for the record, give us a little of your view on that.

Mr. COLE. Yes; I would be happy to.

We feel that the method that EPA has set up to make a determination, not only for certification but possibly for surveillance, is unreasonable in that they require each and every car to meet these very stringent requirements.

Now, if you take the original 1975 standards, Congress intended that there would be a 90-percent reduction in 1975 of HC and CO, from those standards that were obtained from the 1970 certification procedures. Now the way EPA has interpreted this for 1975, it looks as though we must get a 97-percent reduction, and we are approaching, really, zero emissions. As you try to get the tighter control, then it becomes more difficult and more expensive. This is why we said we could not and we have not developed the technology to make the 1976 requirements, which are really the original 1975 requirement without the EPA giving us the interim relief. So we feel quite strongly that through such changes in interpretation of the regulation, and without averaging, that is, each and every car being required to meet the standards for 5-year, 50,000-mile period and with the recall provision in the act, that we are being asked to do something that is technically impossible.

We would recommend that Congress review these techniques that EPA is using for certification and for surveillance—and they are in the process of developing a surveillance procedure—to see if they meet what Congress really intended.

Mr. NELSEN. Yes.

Well, without asking the question, do you feel that they have denied the open door?

I would say that I am sure our committee hopes that they will establish communication because we find that if, when we draft a bill or deal with legislation, that if we consult with the people that will be affected by it, oftentimes we find that some of our ideas could be remodeled a little bit to more completely accommodate the situation.

Thank you, Mr. Chairman.

Mr. COLE. I was just going to remark there, Mr. Nelsen, that I believe the door is open, but the ears are not very wide open at the moment.

Mr. ROGERS. May I just ask some questions quickly, and I will not ask very many.

I would like to just look at 1974 and 1975 now. If we go with 1975, will you get a better fuel economy in 1974 or 1975, General Motors?

Mr. COLE. Better fuel economy in 1975.

Mr. ROGERS. Ford?

Mr. MISCH. Slightly, 3 percent.

Mr. ROGERS. Three percent better in 1975?

Mr. MISCH. 1975.

Mr. ROGERS. Chrysler?

Mr. TERRY. We expect the same, no change. There are factors making it better, factors making it worse. We figure it will wash.

Mr. ROGERS. Now, what percentage of your cars will have catalytic converters in 1974, 1975?

Mr. COLE. For 1974, if you retain the existing standards, there will be no catalytic converters required.

Mr. ROGERS. None.

Mr. COLE. In 1975, it is very likely that we would have close to 100 percent.

Mr. ROGERS. Ford?

Mr. MISCH. None for 1974 carryover. All of California for 1975, and also in 1975 about 65 percent of the cars built for the other 49 States would have catalysts.

Mr. ROGERS. Thank you.

Chrysler?

Mr. TERRY. We figure first, none for 1974. For 1975, Federal interim standards somewhere between 30- and 70-percent catalytic converters, and we are following a flexible certification pattern.

Mr. ROGERS. And for California?

Mr. TERRY. All of California would require catalysts.

Mr. ROGERS. Yes; it would have to, yes.

Now, the use of octane gas, 91, in 1974, and 1975.

Mr. COLE. We have been 91 since 1971.

Mr. ROGERS. All——

Mr. COLE. All cars that we have built since 1971 have an octane requirement to satisfy the antiknock or knock characteristics, or 91.

Mr. MISCH. In either 1974 or 1975, it would be 91 octane.

Mr. TERRY. So far, we are 91 octane and have been and would be in both 1974 and 1975.

However, if the 1974 standards were to be carried over, we would, as soon as possible, increase the compression ratios in our cars to take advantage of this and gain some 4- or 5-percent fuel economy in some or all of our cars, by using leaded gas.

Mr. ROGERS. All right.

Now, the use of unleaded gas. I presume the 91 octane in effect is the unleaded. I suppose it does not have to be, but basically is, so that your same answers would then prevail with the unleaded gas?

Mr. COLE. That is right.

Mr. MISCH. That is right.

Mr. TERRY. That is right.

Mr. ROGERS Now, weight. What is your program for reduction in weight of cars?

Does this affect fuel economy?

Mr. COLE. Yes. Well, I indicated that roughly, rule of thumb, in, say, regular sized cars, 400 pounds meant about 1 mile per gallon and we have a very intensive program to reduce weight.

But on the other hand, another branch of Government, the Department of Transportation——

Mr. ROGERS. On your bumpers and so forth?

Mr. COLE. Bumpers and other safety characteristics that are adding weight and length to our cars.

Mr. ROGERS. What are the requirements of that weight factor, would you think?

Mr. COLE. Well, I indicated in my testimony that we have added roughly 502 pounds.

Mr. ROGERS. Just from the safety regulations alone?

Mr. COLE. It is a combination. When you say just safety, now, you have got to decide whether you want to restore performance or not with the added weight. If you restore performance, then that takes a larger engine. If you have a larger engine, very likely it will take larger brakes, larger tires, larger wheels, and things of this type. And so we can put into the record exactly how much was involved in the DOT requirements directly, and then the——

Mr. ROGERS. I think it would be well for us to have that.

Mr. COLE. All right. We can put that in.

[The following information was received from General Motors for the record:]

VEHICLE WEIGHT NECESSARY TO MEET DOT (SAFETY) REQUIREMENTS

A GM survey indicates that about 240 pounds, which includes the bumper system, have been added to a typical GM passenger car because of safety regulations. It is anticipated that by 1976, if present plans are carried out, an additional 160 pounds will have been added primarily because of Title 1 of the Cost Savings Act and Safety Standards 208—Occupant Crash Protection, and 105a—Hydraulic Brakes.

Weight increases to meet federal standards are shown on Figure 5, which indicates that the largest increase was required to meet exterior protection Standard 215 (bumpers).

Head restraints (FMVSS 202) and side guard beams (FMVSS 214) are additional items requiring substantial weight increases.

Moreover, increases in weight due to safety standards produce the need to make other changes to the vehicle structure, brakes, suspension, wheels and tires. These additions, in turn, make necessary a larger engine to maintain the same performance and emission levels.

An example of these additional safety-related weight factors for a Chevrolet, V–8, 4–door sedan, during the period 1968–73, are:

	Pounds
Disk brakes and suspension	75
Power steering	40
Frame	56
Wheels and tires	54
Engine	119
Total	344

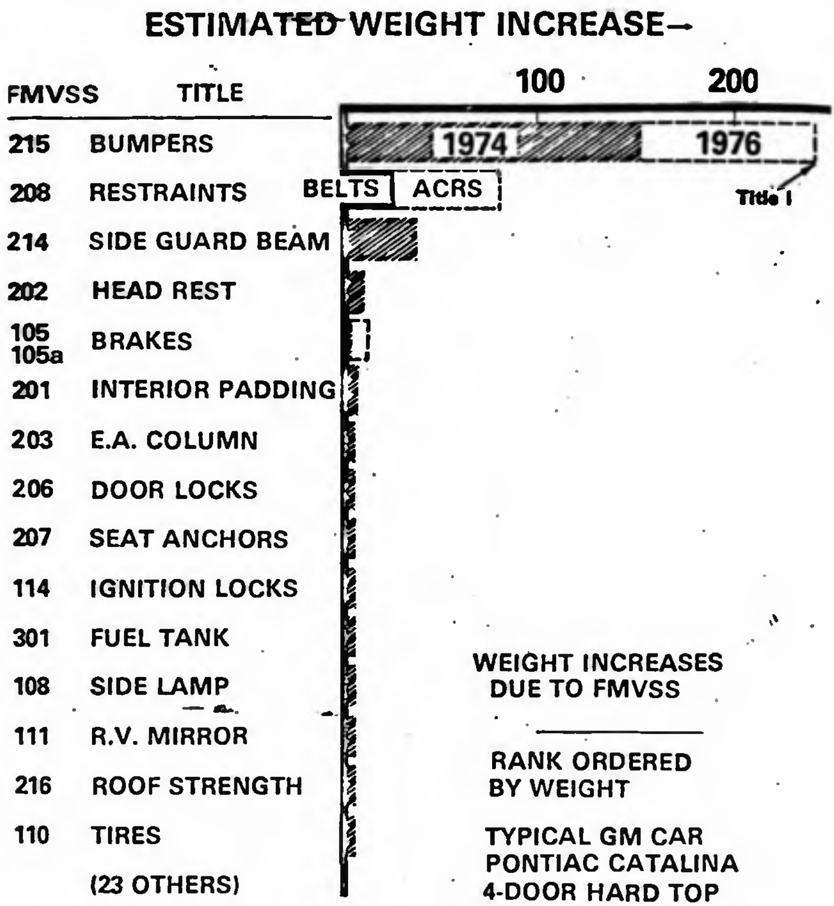


FIGURE 5

Mr. MISCH. All right. We can supply it.

I can give you one stake in the ground. On a full size Ford, about 550 pounds have been added; about half of that is attributable to regulations that require changes in the product to add weight, and the rest of it has been discretionary.

Mr. ROGERS. All right.

[The following information was received from the Ford Motor Co.:]

Effect of Weight and Other Miscellaneous Factors on Vehicle Fuel Economy

WEIGHT

The 1974 Ford automobile has increased 379 pounds (10.1%) since 1967 because of safety-damageability-emissions (SDE) requirements. This weight increase necessitated an engine displacement increase and the combined effect of both was a 7–8% decrease in fuel economy. The weight increase alone accounted for half of this decline. (Reference: R. A. Place, July 17, 1973, Testimony before House Select Committee on Small Business.)

OTHER FACTORS

Air Conditioning—The added fuel consumption caused by the use of air conditioning depends on the thermal input to the automobile, the cycle driven, and on the engine. An approximate estimate of its effect is a 3% increase at 70 mph and an 11% increase in consumption at 40 mph.

Automatic Transmission—According to EPA figures, automatic transmissions introduce a 2% fuel economy loss in large cars; 6% in low power-to-weight ratio cars.

Emission Control for 1974 and 1975—Emissions control at the 1974 49-state levels causes an average 10% penalty in fuel economy. The 1975 49-state emissions standards will result in either a 7% or a 15% fuel economy penalty depending (in the first case) whether catalysts are employed to achieve control.

Mr. Rogers. I am not sure I got the rest of the answer as to what your plans are for weight reduction.

Mr. Cole. Well, we have a very extensive program to reduce weight, but that is going to take some time. And one of the things that is involved is the very lack of, maybe, a forecast of what is going to happen to emission requirements over time. Then, what is going to happen as far as DOT is concerned, adding safety characteristics to our cars.

And we were told by the Secretary that it is very likely, with the things they have in mind, our small cars will get bigger and heavier and the big cars will get bigger.

Mr. Rogers. But for the discretionary portion?

Mr. Cole. Our plan is, naturally, to cut down on these discretionary areas that you speak about. We do not quite agree with Ford that half of the weight increase was completely discretionary. I guess you can say you can decide whether you want to maintain the same performance or whatever you want to do. But a large percentage of our increase went along with the stimulated changes created or caused by the DOT requirements.

Mr. Rogers. What would you be doing on weight now, Ford?

Mr. Misch. Well, we also have rather intensive programs to try to reduce weights in all of our vehicles, plus the fact that the general market shift from vehicles of one size to a smaller size is taking place.

Mr. Rogers. Yes.

And Chrysler?

Mr. Terry. There is nothing new about weight reduction, weight control programs. This has been true before we ever had any regulations. We find, however, that for about—for every pound that we have to put in for regulations over which we have no control, we have to put in about another half a pound in the rest of the car, just to stay even.

Mr. Rogers. Yes.

I have been given some figures, and I think if each of you would submit to the record what you estimate the factor of the impact of full economy to be, such as vehicle weight, air-conditioning, and automatic transmissions. If you could let us have a percentage of the impact on fuel economy for the record, as soon as possible, that would be helpful.

[Testimony resumes on page 335.]

[The following article was submitted by Chrysler Corp.:]

General Factors Affecting Vehicle Fuel Consumption

(By G. J. Huebner, Jr. and D. J. Gasser)

In recent years, fuel economy and acceleration have worsened. The trend will continue, and we may not be able to work our way out of this problem as the rules are written today.

In the main, the degradation of fuel economy and acceleration from 1968 to 1973 has been brought about by two factors—emissions controls, and weight increases. The primary factor in the weight increase has been the addition of mandated safety equipment.

This paper will briefly review the major factors that influence fuel economy and acceleration. Historically, the vehicle designer has been able to trade one for the other. When both depreciate at the same time, design latitude narrows considerably.

MEASURING FUEL ECONOMY

There are two basic types of fuel economy: road-load and cycle. Road-load economy involves steady-state operation on a level road, a condition seldom attained in normal driving practice. Cycle economy, however, can involve acceleration, deceleration, idling, and road-load operation in various relative amounts—depending upon the cycle. We currently measure fuel economy under Urban, Freeway, and Interstate cycle conditions. The urban cycle is most often quoted for comparative purposes.

In Figure 1, road-load fuel economy is plotted against car speed for three vehicles. The sub-compact vehicle has a four-cylinder engine and a manual transmission for extremely good economy. The heavy luxury car has a V–8 engine and automatic transmission. The top and bottom curves illustrate a wide spectrum of fuel economy levels. An "in-between" car, the intermediate vehicle with a V–8 engine and automatic transmission, represents a mid-size car that traditionally provides adequate economy. Because it represents a typical American car, I will use it for evaluating the influence various factors have on its fuel economy and acceleration.

Notice that the peak road-load economy level of each vehicle occurs at about 30–40 mph, and that it drops off rapidly at the higher speeds. While the road-load condition is seldom attained in normal driving practice, its measurement is useful for general fuel economy comparisons. More normal than road-load economy is urban-cycle economy, which consists of four modes encountered in stop-and-go driving.

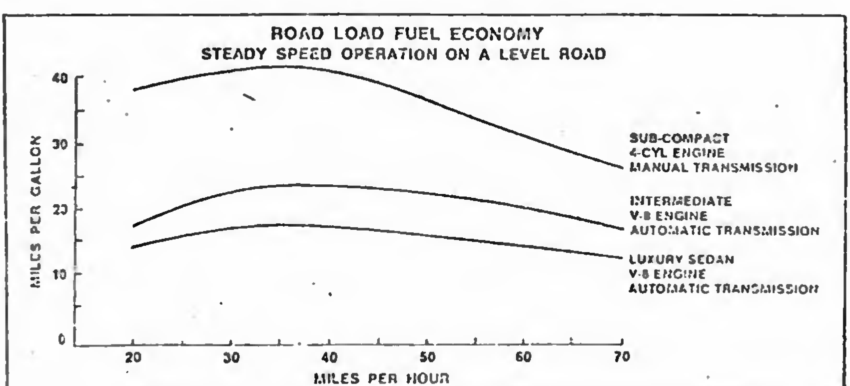


Figure 1

The percentage of time spent in each mode of the cycle are: 16% Idling 31% Acceleration, 18% Deceleration, and 35% Road Load. The urban cycle economy levels are similar to those obtained in the current Environmental Protection Agency emissions test cycle.

There are two phases of urban-cycle economy operation: cold and warm. The cold phase involves the first five miles of operation, where the choke and lubricant warm-up are major factors. The warm phase involves operation after ten miles with a significant improvement over the cold.

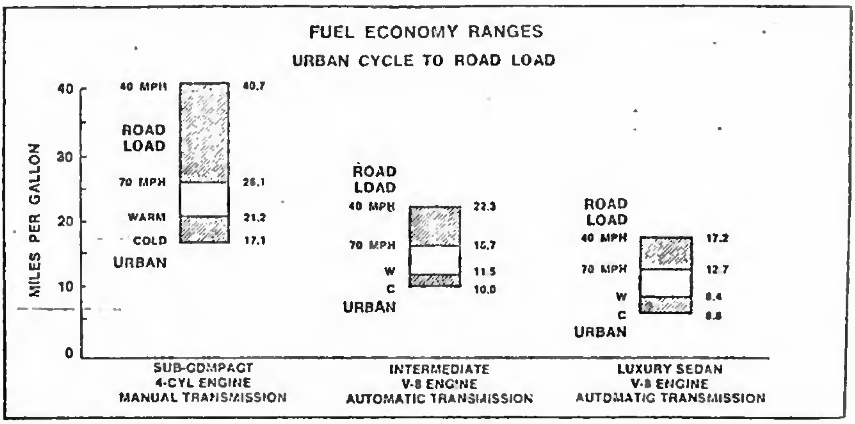


FIGURE 2

In Figure 2, urban-cycle and road-load economy levels of the three cars have been combined to illustrate the ranges that are possible for each vehicle. As expected, for all three vehicles, the highest attainable economy levels occur in the 40 mph road-load condition, while lowest levels occur in the cold-urban condition. Notice, that under certain unique conditions, these completely different vehicles could conceivably produce the same economy level. This is unlikely, but it is possible in the area of about 17 mpg. The warm-urban and 70 mph road-load economy levels represent more-or-less normal conditions, and they will be used for comparative purposes throughout this discussion.

FACTORS AFFECTING FUEL ECONOMY

APPROXIMATE EFFECT OF FACTORS	URBAN CYCLE	70 MPH ROAD LOAD
VEHICLE SIZE AND WEIGHT	80%	90%
TRANSMISSION	15%	5%
ACCESSORIES*	5%	5%

*AIR CONDITIONING NOT OPERATING

FIGURE 3

FACTORS AFFECTING FUEL ECONOMY

There is about a 13 mpg difference in both urban-cycle and 70 mph road-load economy between the luxury and sub-compact cars, while the acceleration levels of these two vehicles are roughly equal. The primary factors contributing to the economy difference are vehicle size and weight, type of transmission, and the car's accessories.

Vehicle size and weight is the most significant factor (see Figure 3). The larger vehicle, at a weight of 5200 lbs. compared to 2100 lbs. for the sub-compact and with a 40 per cent greater body frontal area, requires a large V–8 engine to equal the acceleration level of the small 4-cylinder powerplant in the smaller car. These factors combine to account for 80 to 90 per cent of the economy difference. The transmission effect is primarily due to the fact that the sub-compact is equipped with a manual transmission while the luxury vehicle is equipped with an automatic. The tabulated effect of accessories represents the weight effect of the power steering, power brakes, power windows, and air conditioning which are normally installed on the luxury car but not the sub-compact. This category also includes the power consumption effect of the power steering unit.

The intermediate car has been selected as the sample vehicle for our factor evaluation, because it represents an average American vehicle that provides completely adequate performance. We will look at the effect of engine efficiency and displacement, compression ratio, torque converter, transmission, axle ratio, aerodynamic drag, tires, accessories, vehicle weight, and emissions controls. For the most part, we will investigate ten per cent changes in these factors. It should be noted that the effect of the factors will vary on vehicles other than our average car, but not significantly.

Background information for our factor evaluation is based on a combination of Chelsea Proving Ground test results and performance calculations. The acceleration and fuel economy tests were conducted under established Proving Ground procedures. Historically, the performance calculation technique provides very good agreement with actual test results. The acceleration and fuel economy effects quoted in the factor evaluation are therefore, based primarily on calculated data which have been confirmed by past and current actual vehicle testing.

ENGINE DISPLACEMENT

INTERMEDIATE CAR WITH
AUTOMATIC TRANSMISSION

EFFECT OF A
10% ENGINE DISPLACEMENT CHANGE:

70 MPH ROAD LOAD FUEL ECONOMY 0.1 MPG

URBAN CYCLE FUEL ECONOMY 0.2 MPG

ACCELERATION EFFECT

12% THROUGH GEARS 19% DIRECT GEAR

FIGURE 4

Engine displacement is our first factor for evaluation. *In general, an engine displacement increase results in economy losses and acceleration gains, while a displacement decrease results in economy gains and acceleration losses.* A ten percent displacement change has only a minor effect upon both 70 mph road-load and urban-cycle fuel economy. Notice however, the major effect of displacement on acceleration. Throughout this summary, "through the gears" is a comparison of acceleration from 0 to 60 through all gears, while "direct gear" is a comparison of 50–70 acceleration in direct gear without using a kickdown to a lower gear.

COMPRESSION RATIO

INTERMEDIATE CAR WITH AUTOMATIC TRANSMISSION

EFFECT OF A 10% COMPRESSION RATIO CHANGE:

70 MPH ROAD LOAD FUEL ECONOMY	0.5 MPG
URBAN CYCLE FUEL ECONOMY	0.3 MPG

OCTANE REQUIREMENTS:

10% INCREASE (9.5:1 C.R.)	95
STANDARD (8.6:1 C.R.)	91
10% DECREASE (7.7:1 C.R.)	86

ACCELERATION EFFECT

4% THROUGH GEARS	6% DIRECT GEAR

Figure 5

The general effect of an increase in compression ratio is an improvement in both fuel economy and acceleration, while reducing compression ratio produces economy and acceleration losses. A ten percent compression ratio change has a more significant effect in fuel economy than the previously discussed displacement change. The effect of compression ratio on acceleration, however, is much smaller than the effect of displacement. Note the fuel octane requirement change for the high and low compression ratio engines.

TORQUE CONVERTER

INTERMEDIATE CAR WITH AUTOMATIC TRANSMISSION

EFFECT OF A RELATIVELY LOOSE TO TIGHT CONVERTER

70 MPH ROAD LOAD FUEL ECONOMY	0.2 MPG GAIN
URBAN CYCLE FUEL ECONOMY	0.7 MPH GAIN

ACCELERATION LOSS

1% THROUGH GEARS	6% DIRECT GEAR

Figure 6

The sample vehicle was tested with two torque converters; one relatively loose, and one relatively tight. The relatively loose converter is a small unit usually used on six-cylinder and small V–8 engines. The relatively tight converters is a larger unit with a primary usage in vehicles with large V–8 engines. The change from the loose to the tight converter showed economy gains and acceleration losses. The gain in 70 mph road-load fuel economy resulting from this change is only minor, due to the small slip differences between the converters at high speed. There is, however, a very beneficial gain in urban-cycle fuel economy. The acceleration loss occurs primarily in direct gear operation.

TRANSMISSION

INTERMEDIATE CAR

AUTOMATIC VERSUS MANUAL TRANSMISSION FUEL ECONOMY LOSSES

WITH EQUAL AXLE RATIOS (2.71 AUTO. & MAN.)

70 MPH ROAD LOAD FUEL ECONOMY	1.2 MPG
URBAN CYCLE FUEL ECONOMY	1.8 MPG

WITH "OPTIMIZED" AXLE RATIOS (2.71 AUTO., 2.94 MAN.)

70 MPH ROAD LOAD FUEL ECONOMY	0.5 MPG
URBAN CYCLE FUEL ECONOMY	1.6 MPG

ACCELERATION GAIN:

EQUAL AXLES	"OPTIMITED" AXLES
6% THROUGH GEARS	4% THROUGH GEARS
16% DIRECT GEAR	10% DIRECT GEAR

FIGURE 7

Changing from a manual to an automatic transmission with equal axle ratios results in very significant economy losses. This car is normally furnished with a 2.94 axle ratio for the manual transmission and the 2.71 for the automatic to optimize gradeability and pulling away from a stop. Figure 7, therefore, also includes the effect of the transmission change with the optimum axle ratios. In this case, the economy losses for the automatic transmission are reduced somewhat but remain very significant, although it must be pointed out the manual transmission results were obtained with a skilled driver, whereas the automatic can be consistently the same with an unskilled operator. Note that the acceleration gains for the automatic in both axle ratio examples are also major, especially in the direct gear ranges.

In general, an increase in numerical axle ratio produces economy losses and acceleration gains, while a decrease results in economy gains and acceleration losses. A ten per cent axle ratio change has a significant effect on 70 mph road-load fuel economy. The effect on urban-cycle economy is only minor, however, due primarily to the acceleration and deceleration modes involved in the cycle operation.

The general effect of an aerodynamic drag increase is loss in both economy and acceleration. Conversely, a drag decrease will produce economy and acceleration gains. A given aerodynamic drag change significantly affects only high-speed operation, since aerodynamic horsepower required varies with the cube of velocity. The effect of a ten per cent aerodynamic drag change on 70 mph road-load economy, is therefore, quite significant due to the speed involved. As expected, the effect on urban-cycle economy is negligible because of the low speed involved. The effect of aerodynamic drag on acceleration would be much greater than quoted, if higher speed operational ranges were considered—aerodynamic drag has a very significant effect on top speed.

AXLE RATIO

INTERMEDIATE CAR WITH AUTOMATIC TRANSMISSION

EFFECT OF A 10% AXLE RATIO CHANGE:

70 MPH ROAD LOAD FUEL ECONOMY	0.6 MPG
URBAN CYCLE FUEL ECONOMY	0.2 MPG

ACCELERATION EFFECT

3% THROUGH GEARS	5% DIRECT GEAR

Figure 8

AERODYNAMIC DRAG

INTERMEDIATE CAR WITH AUTOMATIC TRANSMISSION

EFFECT OF A 10% AERODYNAMIC DRAG CHANGE:

70 MPH ROAD LOAD FUEL ECONOMY	0.7 MPG
URBAN CYCLE FUEL ECONOMY	NEGLIGIBLE

ACCELERATION EFFECT

1% THROUGH GEARS	3% DIRECT GEAR

Figure 9

Rolling resistance is primarily dependent upon tire construction. In general, an increase in rolling resistance produces losses in both fuel economy and acceleration, while decreases result in economy and acceleration gains. At low speeds, rolling resistance forms the major contribution to total force required; the aerodynamic drag is the prime contributor at high speeds. The acceleration effect of a ten per cent rolling resistance change is about equal to that previously quoted for aerodynamic drag.

The 1970 Fiberglas-belted tire was about one mpg poorer than the bias, non-belted polyester cord tire previously used. Improvements in this tire reduced the penalty to 0.3 mpg. Steel-belted radial tires can provide 0.3 mpg advantage over the polyester cord.

ROLLING RESISTANCE

INTERMEDIATE CAR WITH
AUTOMATIC TRANSMISSION

EFFECT OF A
10% ROLLING RESISTANCE CHANGE:

70 MPH ROAD LOAD FUEL ECONOMY	0.4 MPG
URBAN CYCLE FUEL ECONOMY	0.2 MPG

ACCELERATION EFFECT

1% THROUGH GEARS 3% DIRECT GEAR

FIGURE 10

ACCESSORIES

✓

INTERMEDIATE CAR WITH
AUTOMATIC TRANSMISSION

EFFECT OF ACCESSORY POWER LOSSES:

	URBAN CYCLE	70 MPH ROAD LOAD
• AIR CONDITIONING	1.5 MPG	1.0 MPG
• ALTERNATOR	0.9 MPG	0.5 MPG
• FAN	0.1 MPG	0.5 MPG
• POWER STEERING	0.1 MPG	0.4 MPG

FIGURE 11

Fuel economy losses for four basic engine accessories are summarized in Figure 11. The effect of air conditioning, which is highly variable with ambient temperature, is quoted at 85° F. Maximum output of about 40 to 50 amperes is reflected in the alternator economy losses. The fan included in this summary is an 18-inch diameter, 7-blade unit. The losses quoted for power steering assume "straight ahead" driving with minor corrections.

VEHICLE WEIGHT

INTERMEDIATE CAR WITH AUTOMATIC TRANSMISSION

EFFECT OF A 10% VEHICLE WEIGHT CHANGE:

70 MPH ROAD LOAD FUEL ECONOMY 0.4 MPG

URBAN CYCLE FUEL ECONOMY 0.5 MPG

ACCELERATION EFFECT

10% THROUGH GEARS 12% DIRECT GEAR

FIGURE 12

It is interesting to note that, combined, the quoted accessory losses amount to about two-and-a-half miles per gallon.

The general effect of a vehicle weight increase is losses in both economy and acceleration, while a weight decrease results in economy and acceleration gains. Ten per cent represents a vehicle weight change of about 350 lbs. in an average car. Only major weight changes such as this will significantly affect fuel economy. Note, however, the very significant effect of the ten per cent weight change on acceleration.

1968 TO 1973 PERFORMANCE TREND

INTERMEDIATE CAR WITH AUTOMATIC TRANSMISSION

	ACCELERATION TIME (SECONDS)		FUEL ECONOMY (MPG)	
	0-60 THRU	50-70 DIR.	URBAN CYCLE	70 MPH R.L.
1968	11.2	8.2	12.4	17.0
1973	12.6	9.5	10.1	16.1
1968 TO 1973 LOSSES	11%	14%	2.3 (19%)	0.9 (5%)

FIGURE 13

Both acceleration and fuel economy estimates for the 1973 package are compared to 1968 levels in Figure 13. The losses in acceleration and fuel economy are very significant as you can see.

Emission controls and vehicle weight increases are the prime contributors towards the indicated major economy and acceleration losses.

EMISSION CONTROLS

INTERMEDIATE CAR WITH AUTOMATIC TRANSMISSION

LOSS TO EMISSION CONTROLS AND RELATED ENGINE SPECIFICATION CHANGES

	URBAN CYCLE	70 MPH ROAD LOAD
1968 TO 1973	1.8 MPG (15%)	0.5 MPG (3%)
1972 TO 1973	1.2 MPG (10%)	0.4 MPG (2%)

ACCELERATION LOSS

1968 TO 1973 = 1972 TO 1973 1%

2% THROUGH GEARS

3% DIRECT GEAR

FIGURE 14

The effect of emission controls on the fuel economy of our "average" car is shown in Figure 14. The major losses occurred in the 1973 changes when exhaust recirculation and delays in spark advance timing were introduced. Acceleration losses related to emissions controls have not been significant during this period.

Vehicle weight is the other prime contributor towards reduced economy and acceleration. Note that the economy losses resulting from the 1968–1973 weight increase are less significant than they were for emission controls. On a percentage basis, however, the acceleration losses are much greater than the economy losses.

VEHICLE WEIGHT—1968 TO 1973

INTERMEDIATE CAR WITH
AUTOMATIC TRANSMISSION

LOSS TO VEHICLE WEIGHT INCREASES ONLY:

URBAN CYCLE	70 MPH ROAD LOAD
0.5 MPG (4%)	0.4 MPG (2%)

ACCELERATION LOSS:

9% THROUGH GEARS   11% DIRECT GEAR

FIGURE 15

This is an appropriate time to discuss the "double effect of weight". For example, let's suppose we are willing to accept the 1968 to 1973 weight increase with its accompanying economy losses, but we are not willing to accept the eleven per cent direct gear acceleration loss. In order to recover this acceleration loss, we increase displacement and axle ratio. This would result in additional economy losses of 0.2 to 0.3 mpg. in the urban cycle, and 0.7 mpg at 70 mph.

The economy losses due to vehicle weight would now be increased to levels of about 0.8 mpg on the urban-cycle and to 1.1 mpg at 70 mph road-level.

While we are on the subject of vehicle weight, look at the 1968 to 1973 trends of three actual vehicles (Figure 16) proves very interesting.

If the trend continues, it won't be long until the compact weighs as much as the intermediate previously did, and the intermediate weighs as much as the standard formerly did.

There are, however, some long range economy improvement areas that are definitely worth future consideration on all vehicles regardless of their accelera- tion capability. Improvements of seven per cent may be possible in the area of engine efficiency. We feel that a 0.5 mpg improvement can be reasonably expected. Aerodynamic drag reduction can be obtained. Transmission modifications require extensive changes, but are worth considering. Overdrive or lower numerical axle ratios have a very significant economy effect when combined with a lock-up converter, especially at higher speeds.

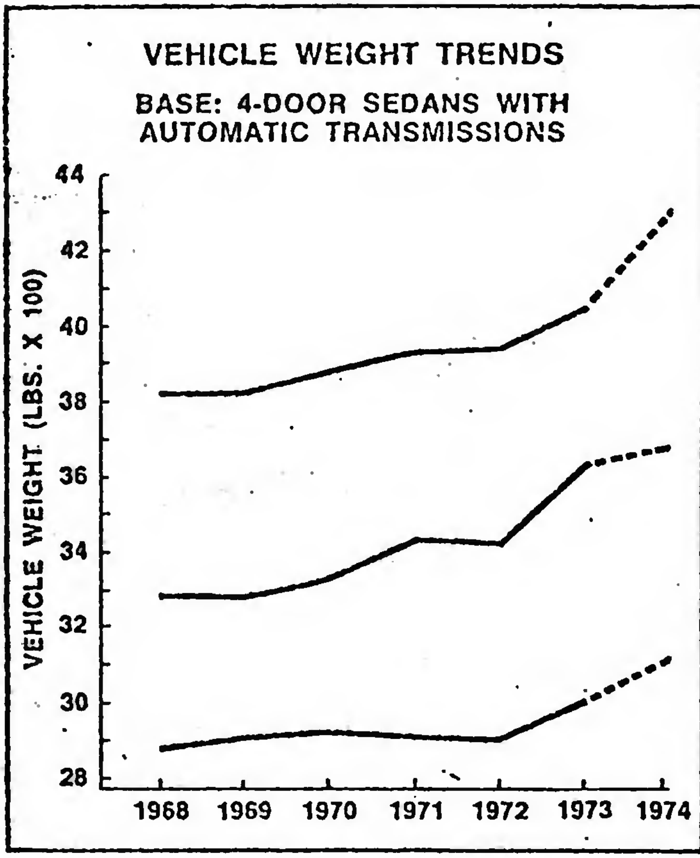


FIGURE 16

CONCLUSIONS

Since 1968, vehicle weight increases and emissions controls have reduced fuel economy substantially, with the bulk of the loss being due to emissions controls.

An additional loss in economy and acceleration is predicted by 1976. Attempts to regain the acceleration losses by conventional means would probably result in further economy reductions.

The impact of the predicted losses can be lessened by using combinations of the following:

Improved engine efficiency.
Improved drivetrain efficiency.
Reduced aerodynamic drag.
Reduced tire rolling resistance.
Reduced vehicle size.

* * *

FUEL CONSUMPTION INFORMATION

The attached chart provides various fuel consumption comparisons of Chrysler Corporation engines. The two columns at the right of this chart are our 1973 and 1974 fuel economy as derived from the EPA certification values. Although the certification data include truck applications of the various engines, only passenger car values were used because the baseline used for comparison was the average fuel economy for the 1020 passenger cars involved in the E.P.A. "six cities" study as calculated by Chrysler. The baseline value used was 13.9 miles per gallon which was the average of the years 1968 to 1970.

Shown on the chart are the production weighted averages for all Chrysler engines. As can be seen, in 1973 the certification values are 14.5% below the baseline; for 1974, they were 12.2% below.

In computing the values that represent current device status *all* values from development cars that met 1975 interim Federal standards were averaged for each car; then the cars, themselves, were averaged by engine types. The results show the following:

Air pump only—8.7% below baseline.
Catalyst only—8.0% below baseline.
Catalyst plus air pump—9.5% below baseline.

Obviously, nothing that we have tried in our development programs indicates the possibility of major fuel consumption saving with or without catalysts. Actually, even the slight improvement indicated over 1974 is doubtful if 1975 interim standards are adopted, since some penalty will be incurred in order to provide a safety factor for production. If the 1974 levels are maintained, this penalty would not be required.

FUEL CONSUMPTION, CHRYSLER CORP. ENGINES

Engine	Percent production	1975 development vehicles (miles per gallon)			1973 cert.	1974 cert.
		Catalyst (No air pump)	Catalyst (with air pump)	Engine modification		
198 in³	0.63	17.1	19.2	18.1	17.9	15.4
225 in³	28.15	16.0	16.3	16.1	16.1	16.5
318 in³	15.29	12.3	12.15	12.7	11.4	12.4
360 in³	13.79	10.6	10.5	10.8	9.7	10.35
400 in³	23.79	11.3	10.9	10.5	9.5	9.0
440 in³	6.97	9.2	9.1	9.8	9.4	9.0
Weighted average (miles per gallon)		12.8	12.6	12.7	11.9	12.2
Below baseline 1968–70 valve (13.9 miles per gallon)		8.0	9.5	8.7	14.5	12.2

Note: All tests run by FPA method.

Mr. ROGERS. Are there any other questions?

Yes, Mr. Satterfield.

Mr. SATTERFIELD. Mr. Terry, I would like to ask you this question, and I would like to have your comments, if we may, on the question of what economy gains could be claimed if we go to catalysts in 1975. There seems to be a disagreement on this, and I would like your views.

Mr. TERRY. Well, we said that we would be lucky to break even in 1975 if we go to catalysts, compared to where we are in 1974. And I said there were some counteracting factors.

The first is that if we go to catalysts, we know we are going to have to use lead-free gas, and if we know we have to use lead-free gas, it means that it is going to be 91 octane, if we are lucky. This means we have got a problem that people do not have today. We can design the car to run on 91 octane gas, but there may still be some 20 or 30 percent of the cars that will not be able to run very well on 91 octane, so they can always go out and get some leaded gas at higher octane and still run.

However, if the only thing we can use on this car is 91 octane, we are going to have to make our actual octane tolerance lower than 91 in order to be sure and take care of our cars whenever they get this lead-free gas. So we figure we are going to have to sacrifice some fuel economy with lowering the compression ratio or changing spark or some combination thereof, and that that will cost us fuel economy.

Now, on the other hand, we expect to get a little bit back by being able to retune the engine, because we have got the catalyst to clean up some emissions that we might not otherwise have. And those two factors, from our running to date, seem to be about equal, so we are saying that we think we will break even if we are lucky in fuel economy.

Mr. HEINEN. Let me add one small comment here. We have done this to a number of the cars. We have set them up for meeting the 1975 standards with the catalyst. We have taken off the catalyst, and they now meet the 1974 standard. We have learned how to get a 3-percent improvement in fuel economy which will be inherent to the car. The catalyst itself neither adds to nor detracts from economy, so that if we were to carry over 1974 standards, we could get that 3 percent. If we go to 1975, we can get that 3 percent over and above everything else that Sid has mentioned here, that is—I mean by break-even.

Actually, if you add the couple of items that you mentioned, why, we might come out further ahead, but 3 percent is all we have been able to get in the way of improvement at the 1975 standards levels with the catalyst.

Mr. SATTERFIELD. Well, if you went to the increased compression ratio that Mr. Terry mentioned, this would be on top of this 3 percent?

Mr. HEINEN. Yes, right.

Mr. TERRY. Yes, right.

Mr. SATTERFIELD. And you say it would be 4 to 5 percent, so it would be 7 or 8 percent if we freeze at the 1974 levels that you could enjoy?

Mr. TERRY. Yes, sir. This would take some time for us to do. We might not do it right away for 1975, because it would——

Mr. SATTERFIELD. But at least it is a prospect?

Mr. TERRY. We would at least get it for 1976 for sure.

Mr. SATTERFIELD. Mr. Misch, I wonder if you would like to address the question, sir?

Mr. MISCH. Well, I think I would like to clarify one point. The difference in some of these percentages that each of us might project certainly depends upon the base that we start from, and undoubtedly we start from a somewhat different base.

Now, all of my numbers have been compared to an emission uncontrolled vehicle. In attachment A, I show that in our average 1973 model we attributed a 13-percent loss in fuel economy due to emission controls, as compared to uncontrolled.

Now, in 1974 we improved by about 3 percent. We just did things a little bit better. So, then compared to an uncontrolled base, we were about a 10-percent loss.

Now, in 1975 with catalysts, to meet a 1975 standard, we say we can improve another 3 percent from 1974, which makes us, then, a minus 7 percent from base or uncontrolled. Those vehicles that would not have catalysts we say would not improve the 3 percent, they would depreciate 5. In other words, they would be about 15 percent below uncontrolled base. But, because of the percentages of them, the ones that are 15 percent below base would be about 35 percent of the volume, and the ones 7 percent below would be about 65 percent. That means our average full economy for 1975 models would be about equal to 1974 models.

Mr. HEINEN. May I just ask one question for clarification?

You were talking about those that would meet the 1975 standards without catalysts?

Mr. MISCH. That is right.

Mr. HEINEN. I was talking about those that would meet the 1974 standards.

Mr. MISCH. I was coming to that. First, those would meet the 1975 standards. Then, if we were to carry over the 1974 standards—in other words, we would project that the carryover standards would allow us to have the same fuel economy on Ford cars as the 1975 interim standards with that mix. So I think we are saying pretty much the same thing, here.

Mr. SATTERFIELD. Does that compare with your base?

Mr. TERRY. Yes, I believe so.

Mr. HEINEN. Within a percent, almost every one.

Mr. SATTERFIELD. I was wondering, Mr. Misch, if we impose the 1974 standards, would you be able to increase your compression ratios, too? Would this be an additional bonus?

Mr. MISCH. Well, there is a possibility, although I doubt seriously if we would for 1975. We might for 1976.

Mr. SATTERFIELD. Well, one of the things that impresses me, it seems that what maybe all of you are saying in a different way is the uncertainty that we have had with respect to when you had to meet certain standards has really made it very difficult for you to plan effectively.

Is that basically correct?

Mr. MISCH. That is certainly correct.

Mr. COLE. That is certainly correct.

Mr. TERRY. Amen.

Mr. SATTERFIELD. Well, does not it make sense—I know that two of you have indicated that if we froze it at the 1974 level, that it would make sense to give you time.

I just wonder, Mr. Cole, would not this also give you the time to do what must be done in the long-range?

Mr. COLE. No, we think we have done it.

Mr. SATTERFIELD. In other words, if we were to standardize the levels of 1974, say for 3 years, you would still work, say toward installing catalytic converters on the 977–78 models?

Mr. COLE. We have examined alternate power sources, stratified charge engines for a number of years; turbine engines, diesel cycles, sterling cycle, Ranklin cycle. We have put a lot of effort in this area, and it appears to us that the catalyst gives us an opportunity to make the internal combustion engine as efficient as we know how to make it. And it is a very efficient powerplant, otherwise we would not be using it for 50 years.

And with the addition of the catalyst, we are able to make that engine as clean an engine as any that we know about.

Mr. SATTERFIELD. Well, if you can do that and actually save fuel; I am wondering why you have not put them on the 1974 models?

Mr. COLE. Well, first of all, we operate in a free, competitive market. We have suggested that the only way you are going to bring people together, particularly where there are health effects or safety and things of this type involved, is for Government to make that determination. Government is the only operation that can make it.

The public is not interested in paying more money to get a cleaner car. We could have a zero emission car that would cost $150, say, more than the car that was pretty bad on emissions, and you would not be able to sell it. Do not forget we operate in a free competitive market, and a very competitive one, I might say, too.

Mr. SATTERFIELD. If you can save 13 percent, as you claim, I think that would be a pretty good selling point.

Mr. COLE. We might be able to sell it, and we may try.

Mr. SATTERFIELD. Well, I would like to ask you this, too. We were talking earlier, when I asked you questions about the pool. Yesterday, we had the American Petroleum Institute, a representative from Mobil Oil, and a representative from Texaco, and they testified that there would be a substantial energy loss in the production of 91 octane, nonlead gasoline.

You seem to disagree with that, and I wondered if you could tell me why we should not believe them. Where are they wrong?

Mr. COLE. Well, we are not in the refining business, and you have to assume they are right. We commissioned an outside organization that we have great faith in to examine it, and they have come back and reported to us now that 50 percent of the fuel that is made available for 1975 could be made unleaded, and even more without a penalty on crude.

We will submit that data to you, and then you can determine for yourself, because we are not in the refining or oil distribution business, and I would rather stay out of this part of the argument.

Mr. SATTERFIELD. All right.

Let me ask you one other question. Somewhere in your testimony, it might have been in response to a question that I asked, we were talking about the weighted sales, was that whatever formula you use——

Mr. COLE. Sales weighted.

Mr. SATTERFIELD. Sales weighted.

In answer to my question, I understood that you said that 3 percent of the 13 percent you would pick up was allocated to the additional production of small cars.

Mr. COLE. That is correct.

Mr. SATTERFIELD. I would be interested in knowing what percentage of the 1973 GM models were small automobiles.

Mr. COLE. Well, the category—how you categorize small, intermediate, subcompact is a most difficult kind of a thing. What we will do—I do not have that information right on the tip of my tongue, but I would say about 25 percent of our cars that we produce could be classified in the small area, and that is with six-cylinder engines and that sort of thing. But we will put that into the record as accurately as we can.

Mr. SATTERFIELD. I would appreciate that, as well as what percentage of the same standard of small car you expect for 1975.

Mr. COLE. We will do that, and of course, right now we are capacity limited for small cars, and we will be capacity limited for 1975, because what we do for 1975, we have already practically done, and there is no way to change that very much. So we can give you a pretty good picture of how many small cars we will probably sell, but we cannot tell you how many big ones we will sell.

[The following information was received for the record:]

GM Small Car Sales in 1973 Model Year

General Motors sales of "small cars" in the 1973 model year constituted 22% of its total new car sales. The "small car" definition, for purposes of this statement, is typified by the following GM models: Apollo, Camaro, Vega, Nova, Omega, Firebird and Ventura. When "intermediate"-sized cars are added, the percentage increases to 50% of GM's total sales.

* * *

GM Small Car Sales Projected for 1975 Model Year

Due to the increasing demand for small cars in the market, GM began last year a $300 million shift of production emphasis to respond to this trend. However, the Arabian/Israeli war and the oil embargo imposed new factors on the new car market which have necessitated a reevaluation of future production plans. Since new car production depends upon many long lead-time factors, a realistic projection of rather specific 1975 market conditions for GM products is unavailable at this time. However, our current sales of intermediate and smaller-sized 1974 model cars are running approximately 52.7% of our total sales.

It is safe to say that, with the small car demand in the market strengthening, GM will do all in its power to provide its customers with both the number and type of new cars they wish to purchase.

Mr. Satterfield. I have one final question I would like to ask Mr. Terry and Mr. Misch, and that is what is your assessment of the catalytic converter in terms of longevity?

Do you consider this to be a temporary interim device to meet standards, or do you feel that we will have it permanently, and that you will not be able to look to a different type engine or different parametered engine?

Mr. Terry. Well, we feel definitely that it is temporary. And we do not think that catalysts will be a long-term solution to the emissions problem, or in conjunction with the piston engine or any other kind of engine. We are looking for better solutions.

We do have to have some idea as to where the emissions controls are going to end up in order to even evaluate these other powerplants. But we feel that if the catalysts do go in, that they are going to be a short-term matter.

Mr. Satterfield. If we granted a moratorium, would you begin to work immediately on an alternative solution?

Mr. Terry. We certainly would.

Mr. Satterfield. Mr. Misch?

Mr. Terry. We already are.

Mr. Misch. I think we look at catalysts as probably playing a role for a long time in the solution to the emissions control problem. I think we, down the road, look at quite a mixture as to what might be required. That is one reason why we are suggesting that we have a carryover 1974 to avoid the catalyst requirement just at this time, just during this energy situation.

Now, we still have—and I did not make the point, although I made it in my last testimony—to consider what might happen in California. And before when I was here, we were opting for a two-tier approach whereby California—which has one of the most severe problems—of their own volition, would ask for a waiver that would require catalysts. That would be 10 percent of our Ford production if we just satisfied the California market.

So it would be an excellent production tryout. We are not asking for a moratorium or carryover standards of any kind without also suggesting that a firm standard be established for 1977 or 1978, whatever the case may be, on the length of carryover. So that firm standard could be the target toward which all of us could work.

Let catalysts be "the horse to beat," if you will. There are other approaches. We happen to think there are some. We are putting a lot of investment in some other approaches that would avoid catalysts, but not across the board.

If you just look at the problem, it is going to be many years before we could convert all of our engines to some other approach. So we are saying catalysts are going to be there. We are not sitting here saying, "Give us a moratorium so we can put the catalysts people out of business." That is not true.

Mr. SATTERFIELD. I am not suggesting that, but you would use this time to try to develop some alternatives. And would it help here if you had the time to do it?

Mr. MISCH. Yes, sir. It would.

Mr. COLE. Could I speak to that?

Mr. SATTERFIELD. Yes, sir.

Mr. COLE. We have been using the time for about 20 years to try to come up with alternate power systems, and I indicated that earlier. And we find in our work there are certain unregulated emissions that come out of stratified charge engines that could be very easily regulated, because they are aldahydes that are very reactive. And the only way we know how to clean those up is through a catalytic conversion.

So you could end up with a very expensive stratified charge engine, and still need a catalyst. And I cannot understand why people think catalysts are all bad. It is the same kind of a thing that all of the farmers use. It is a sceptic tank at the end of the line, and for whatever escapes you convert it. I would like to take on Mr. Terry for just a moment in this area, and comment on his statement that when the catalyst goes bad, the engine puts out higher emissions.

Well, what happens when you do not have a catalyst, and the engine goes bad? This is—if you have got a good catalyst, why it takes care of that situation.

Mr. TERRY. Well, the advantage, of course, is that when the engine goes bad, a spark plug misses and you get 10 times as many hydrocarbons in a car where a spark plug is missing, you know there is something wrong with the performance of the car.

When a catalyst goes bad, you do not know that. And you can go ahead running indefinitely with the catalyst completely inoperative and not even know the difference.

Mr. MISCH. Mr. Chairman?

Mr. ROGERS. One more comment.

Yes, sir.

Mr. MISCH. Would it be presumptuous of me to suggest that perhaps I could point out two or three areas where we seem to be in agreement at least, and maybe we differ on others?

Mr. ROGERS. Yes.

Mr. MISCH. We are all saying that we are asking Congress to take action on the 1976 standards by the end of the year, and also indicate what, if anything, is going to be done with regard to 1975 by the end of the year.

We all also are asking——

Mr. ROGERS. Of this year?

Mr. MISCH. Of this year.

We are also all of us asking for some guidance as to what the ultimate NO_x standards would be, so that we could direct our future work more appropriately toward that standard. The other thing we are asking for is that whatever action is taken, that would bear upon whether or not unleaded fuel is going to be required, be done expeditiously.

Those are the things, I think, we are agreeing on.

I think we have some other common positions. We are all saying that if you use leaded fuel on catalyst cars, consistently, it would ruin the catalyst. If you do not use it too often, maybe they will spring back. We are saying when you convert to all unleaded fuel it will ultimately result in some less yield from a barrel of crude oil.

And we also are all saying that when you tighten the NO_x standards, you are going to get poorer fuel economy. I think we have all agreed on that, and I think we have said that there is a fuel economy benefit from catalysts that varies from about a "wash" in the case of Chrysler to 13 percent improvement according to General Motors. Actually, 10 percent according to General Motors, I guess for the catalyst itself.

Ford is saying catalyst versus no catalyst is about 8 percent. So we are probably not quite as far apart as people would imagine.

And the last thing is, I think we agree, if we could do it and still control emissions, higher compression ratios would help fuel economy.

Mr. ROGERS. Thank you.

Any other questions?

Mr. CARTER. Mr. Chairman, just one or two more points here.

Mr. ROGERS. Quickly if we could.

Mr. CARTER. Yes, thank you, sir.

I have heard some rather important people in the motor industry say that they had checked air going into cars, and that in some cases there were more pollutants in this air than were in the exhaust emissions.

Is that correct?

Mr. COLE. It can happen.

Mr. MISCH. It can happen.

Mr. TERRY. It is possible.

Mr. MISCH. It is possible at times that the actual ambient hydrocarbons in the test laboratory can be higher than the control levels on a 1975 vehicle.

Mr. CARTER. I read the preliminary statement of Yale University, and I was very much interested in that. I did not know that you had commissioned this group to do it. But I want to compliment you on it.

And in that preliminary statement, I believe, they at least intimated that some of the noxious substances, or some of the substances, which we have set standards for and considered noxious may not be the ones that cause the most trouble at all. Is that correct?

Mr. TERRY. That is correct. That is very possible. We have to define what a pollutant is, you know. We say hydrocarbon is a pollutant, but there are hundreds of different hydrocarbon compounds. Some of them lead to photochemical smog; some of them have nothing to do with it. The same is true of oxides of nitrogen. We have NO, NO_2 and N_2O_3 at least, which are all different, and have different effects. But the standard does not take that into account.

Mr. CARTER. Final question. Do you think there is any way you can reach the 0.41 NO_x standards by 1977?

Mr. TERRY. No, sir.

Mr. MISCH. No, sir.

Mr. COLE. No, sir, and furthermore, we cannot reach the HC and CO standard by 1976 or 1977.

Mr. CARTER. None of it by that time?

Mr. COLE. That is right.

Mr. CARTER. Thank you. And I feel you gentlemen are telling it as it is.

Mr. ROGERS. Mr. Hastings.

Mr. HASTINGS. In my usual brevity, just one question. It has nothing to do with the subject matter at hand, but we very seldom get all three of you represented in front of us. And I have been very unhappy about the Department of Transportation, and its mandate that you go to the interlock system between the seatbelt and the ignition.

And I would just like you, if you will, and you could make this off the record, it is perfectly all right with me. Are you having any difficulty with the interlock system at GM? Out in the field now where they are in operation?

Mr. COLE. Yes, we are having difficulty.

Mr. HASTINGS. That is all I want to hear, sir.

Mr. COLE. In two ways, and this is customer dissatisfaction with the principle of the system, and some failures.

Mr. HASTINGS. That I agree with.

OK?

Mr. MISCH. Not too many failures, but we are having customer dissatisfaction. But I want to hasten to say that if we can get people to use these belts, it is going to save lives.

Mr. HASTINGS. I did not want the editorial. I just wanted the answer.

Mr. ROGERS. He does not want to hear the truth.

Mr. HASTINGS. You sound like DOT now.

Mr. TERRY. We are having some dissatisfaction in the field, yes, sir.

Mr. HASTINGS. Thank you very much, Mr. Chairman.

Mr. ROGERS. Gentlemen, you have been most kind and helpful to us. We are sorry to impose on you.

Mr. COLE. Could I just add one thing, Chairman Rogers?

Mr. ROGERS. Yes.

Mr. COLE. That I witnessed the production of the first air cushion car that we turned loose to the public just last week. Whether it is good or bad——

Mr. HASTINGS. Were you gratified?

Mr. COLE. Very gratified. We have 1,000 in the field.

Mr. ROGERS. Is that right? Terrific.

May I say we still have some witnesses to hear. We are going to do it as quickly as possible. And before members get away, too, we are meeting at 9 o'clock in the morning to hear either Mr. Simon or his assistant from the Energy Office.

Thank you for being here, and we are most grateful for your testimony.

It would be most helpful if we could get the information for the record as soon as possible.

Our next witness is Mr. Brian Ketcham, Office of Planning and Implementation, Department of Air Resources, the city of New York.

And he is accompanied by Dr. William D. Balgord, New York State Department of Environmental Conservation.

The committee wishes to express to you our appreciation for your help to the committee, and your willingness to bear with us in our time schedule. It was all upset with the meeting of the full committee.

We will be glad to receive your statement, and any comments you would like to make.

STATEMENT OF WILLIAM D. BALGORD, PH. D., SENIOR RESEARCH SCIENTIST, NEW YORK STATE DEPARTMENT OF ENVIRONMENTAL CONSERVATION; ACCOMPANIED BY BRIAN KETCHAM, CONSULTANT; AND STEPHEN WILDER, AUTOMOTIVE SPECIALIST, CITY OF NEW YORK DEPARTMENT OF AIR RESOURCES

Mr. BALGORD. Thank you.

My name is William D. Balgord. I am senior research scientist for the New York State Department of Environmental Conservation. With me are Brian Ketcham, a professional engineer, and Stephen Wilder, an automotive specialist. Mr. Ketcham and Mr. Wilder are with the City of New York Department of Air Resources.

Mr. ROGERS. We welcome you gentlemen to the committee, and I appreciate your patience.

Mr. BALGORD. We are not here in our official capacities, but only as concerned citizens.

Mr. ROGERS. I understand that.

Mr. BALGORD. The 1974 model year cars have lousy gasoline mileage. How come?

It is popular to blame this on the environmentalists, but to say you cannot have clean air and good fuel economy is wrong. Let me explain.

There are two fundamentally different ways to clean up the exhaust fumes from the piston engine. One is to add on devices which detoxify the fumes, like a filter on a cigarette.

The other is to alter the actual combustion chemistry with changes in the carburetion and spark timing. This means tuning the engine for minimum emissions rather than for peak power efficiency. This is sort of like cigarettes made from denicotinized tobacco. And to stretch the analogy, we must admit that the new flavor is not very popular. This is called the engine modification approach.

Detroit is very, very cost conscious. When you build 10 million cars a year, a penny saved is $100,000 earned. Since there is no cost difference between an advanced spark setting and a retarded one, between a small hole in a carburetor jet and a smaller one, Detroit prefers the engine modification approach. After all, add-on devices cost money. Money to make and money to install.

The drawback to engine modifications is that while the exhaust does get cleaner, the engine suffers in other ways, sometimes badly. All of you are probably familiar with the late-model cars that are hard to start when cold and, once warm almost as hard to stop. With engines that idle roughly, stall frequently, and sometimes burn their valves.

But what concerns us most is that gas mileage has gone down and down and down. These drawbacks put a limit to how much you can clean up the exhaust with engine modifications without making the engine so unpleasant that the customer will not tolerate it. I suggest that we are at or close to that point with our 1974 cars.

There are doomsayers who insist we can go further; that 1974 is as far as we can go, as clean as we can stand. They imply that if the standards get any tighter, then all the side effects will get worse. They are wrong.

As the standards get tighter, the carmakers will have to shift to the add-on approach.

The advantage of the add-on approach is this: Add-on devices such as the catalyst enable the engine designer to tune the engine for ideal performance for power, economy, smoothness, and long life. An engine freed of engine modifications can be designed to develop power from its fuel as efficiently as possible. The pollutants are captured and controlled after the power is generated.

It has been said that even with the add-on approach, or with a combination of both approaches, it is simply not possible to meet the statutory limits originally scheduled for the 1976 model year. This, too, is wrong.

I have put together an add-on system on a 1972 Matador using dual-bed catalysts, using existing technology and existing hardware and it meets those stringent standards. It meets them without the enormous loss in fuel economy that we have been told is inevitable. In fact, at expressway speeds, this system appears to offer the same improvement as cutting one's speed from 70 to 50 miles an hour.

Furthermore, this add-on system does this with none of the driveability problems that plague consumers today. This car is easy to start and it does not stumble, stall, or hesitate. Finally, it will cost very little more than the catalyst system GM is planning for 1975 California cars, as it is only a modest extension of that system.

I have a formal report on this system and its first 25,000 miles which I submit for the record. My colleagues and I will be glad to answer any questions you may have.

[The status report referred to follows:]

Status Report

Emission Characteristics of a 1972 American Motors Matador Equipped With a Balgord Dual-Bed Catalytic Emission Control System After 25,000 Miles of Service Testing

(By Dr. William D. Balgord, Senior Research Scientist, New York State Department of Environmental Conservation—December 3, 1973)

Abstract.—A 1972 Matador has been made to meet the original 1976 (now 1977) emission standards for 25,000 miles, the distance at which EPA permits

catalysts to be replaced. The modifications consist of a dual-bed catalyst system with air injection, a 10° spark retard during the initial 90 seconds, and 14.0:1 air/fuel ratio carburetor jetting. Fuel economy and acceleration are improved over the base car. Driveability is equal to pre-1968 uncontrolled engines.

In May of 1973, the New York State Department of Environmental Conservation equipped a 1972 American Motors Matador with a prototype exhaust emissions control system and subsequently found the vehicle capable of meeting the original 1975–76 federal standards for total hydrocarbons, carbon monoxide, and nitrogen oxides. The vehicle, V.I.N. A2A157H298783, is a four-door sedan with 304 cubic inch displacement V–8 engine, automatic transmission, power steering, and curb weight of approximately 3,500 lbs. Its current odometer reading is greater than 50,000 miles. It is one of a fleet of identical vehicles purchased under New York State contract in 1972. Since delivery, the vehicle has operated exclusively on Amoco commercial-grade, lead-free gasoline and ARCO developmental ashless engine lubricant. Routine maintenance has been performed at factory-specified intervals.

The dual-bed catalytic system, which in its present form has been on the vehicle for more than 25,000 miles, consists of parts obtained from American Motors, Engelhard Industries, Gould Laboratories and Maremont Corporation. Its essential features are: 1) air injection to two points in the exhaust system, 2) carburetion adjusted to approximately 14.4:1 air-to-fuel ratio by weight at steady speeds and road load, 3) a dual-point distributor to provide 10° retarded spark during the initial 90 seconds after cold-start, 4) two Gould reduction catalysts, and 5) two Engelhard PTX oxidation catalysts.

Averaged emission levels in five tests (Table I) taken at 25,000 system miles are:

	1976 original standards
Hydrocarbons (HC), 0.32 grams per mile	0.41
Carbon monoxide (CO), 1.86 grams per mile	3.40
Nitrogen oxides (NO_x), 0.36 grams per mile	.40

Although many others have achieved such control of HC and CO, this degree of NO_x control is unique.

Because of the importance attached to the current state of technology regarding control of nitrogen oxides, linear regression analysis of the NO_x data obtained at 2,500, 4,000, 9,000, 16,000 and 25,000 miles (shown in accompanying table) was performed. Statistical analysis showed the NO_x level at 25,000 miles to be 0.40 grams/mile (standard not exceeded) with a correlation coefficient of 0.97. It may be inferred from the statistical data, with a high degree of certainty, that this automobile meets the rigorous standard of 0.40 grams/mile NO_x emissions at 25,000 miles in addition to the hydrocarbon and carbon monoxide standards of 0.41 and 3.4 grams/mile, respectively. Since EPA rules permit replacement of all catalysts at 25,000 miles, it may be inferred that this system is capable of meeting the 50,000 mile certification criteria. In so doing it is the first vehicle to have demonstrated the ability to meet the original 1976 standards.

Fuel economy determined by the EPA "carbon balance" method at low speeds show little difference from EPA data for the same make, model and engine class. However, in-use fuel economy has been improved 20 to 25 percent relative to the other 1972 Matadors operated by the State of New York. Cumulative fuel economy relating mostly to highway and turnpike driving on a large fleet of 1972 Matadors operated by the State is approximately 13 miles per gallon. Under similar driving conditions, the test vehicle has averaged 16 miles per gallon. On a recent trip of 800 miles in five legs at average speeds of 68 MPH, fuel consumption was 17.5, 18.3, 18.6, 18.7 and 20.0 miles per gallon. An in-line fuel meter (specified at ±0.8% error) was used. The odometer has been checked repeatedly and found to have a slight negative error, i.e., more miles actually accumulate than register on the odometer.

Performance and driveability of the modified vehicle are superior to other 1972 Matadors in the New York State fleet. Modified carburetion, set slightly rich of stoichiometric, has reduced tendencies of the engine to stall when cold and has eliminated the off-idle flat spots. Unlike 1973 models with exhaust gas recycle (EGR), there is no perceptible stumble and surge during acceleration and there are no fluctuations at high-speed cruise. Acceleration from zero to 60 MPH takes 11.9 seconds. By comparison, a 1973 Matador with the same engine and transmission but equipped with EGR required 15.0 seconds under the same driving conditions (level ground, dry pavement, low wind speed).

The improved performance and fuel economy relative to stock 1972 Matadors is attributed to several factors: (1) avoidance of overly lean carburetion which results in occasional misfire, (2) a distributor advance curve tailored to minimum advance for best torque which improves efficiency (fuel mileage) at part-throttle cruise, and (3) by-pass of the transmission-controlled spark advance speed switch provides normal spark advance at all speeds and in all transmission ranges whenever coolant temperature is above 160°F.

The prototype vehicle has been subjected to the habits of several drivers, to repeated indoor testing as required by the Federal Test Procedure, and to adverse ambient conditions: cold start at −15°F, 70+ MPH operation at 95°F, the salt and chuckholes of winter roads, and sizeable hills in New York and adjoining states. On one ocassion it was driven to the top of Whiteface Mountain (elevation 4,700 feet) for a series of experiments. The distribution of usage is estimated as follows: city-suburban 40%, highway 20%, turnpike 40% of miles driven.

About $50,000 has been spent to carry out the study of the dual-bed catalyst vehicle, not counting the donation of parts by Gould and Engelhard and performance of emissions tests by EPA, Gould and the New York City Department of Air Resources.

TABLE I

[Test—1975 Federal Test Procedure (LA-4 cold/hot test with constant-volume sampling); Car—Modified 1972 American Motors Matador (304 CIC V-8, auto. trans.) equipped with Balgord dual-bed catalytic emission control system]

System mileage and test lab	Grams per mile— Hydrocarbons	Carbon monoxide	Nitrogen oxides
2,500:			
New York City Department of Air Resources, Bureau of Motor Vehicle Pollution Control	0.30	1.44	0.08
Do	.23	2.30	.16
4,000: EPA Motor Vehicle Emission Laboratory, Ann Arbor	.33	2.99	.11
9,000:			
New York City Department of Air Resources, Bureau of Motor Vehicle Pollution Control	.36	3.18	.23
Do	.37	3.86	.19
16,000: Gould Laboratories, Cleveland	.30	3.30	.32
25,000:			
Gould Laboratories, Cleveland	.24	1.78	.29
Do	.34	2.06	.33
Do	.25	2.20	.36
EPA Motor Vehicle Emission Laboratory, Ann Arbor[1]	1.01	3.37	.40
Do.[1]	.68	3.22	.32
Do	.40	1.58	.36
Do	.37	1.67	.47

[1] Engine false started and stalled several times because the driver failed to follow starting instructions. This resulted in unnecessarily prolonged cranking and, as the other tests at this mileage show, exorbitant emissions of HC and CO. Because the starting procedure was improperly executed, the EPA agreed to perform additional tests. It is the valid data from the latter which are used in this paper's calculations.

Responses to EPA criticisms of the Balgord dual-bed catalyst system:

1. The system required fine tuning before each emission test.

This is true but unimportant. The Balgord car is equipped with a conventional carburetor. General Motors has now developed a "pressure compensating" carburetor which automatically makes the same adjustments to compensate for changes in barometric pressure. Such carburetors were not available to Dr. Balgord in time to be part of this prototype system but they are now available for test and development use. Such carburetors would eliminate the need for recalibrating the carburetor before an emissions test.

2. The spark timing and the air injection are altered manually during the test, an unreasonable requirement for an ordinary motorist.

This is a matter of money, not of technology. On a prototype system of any design, it is normal engineering practice to simplify the expensively handbuilt mechanism at the cost of complicating its operation. The purpose of this prototype system is to test the concept, not make it easy to use. Subsequent examples of the Balgord system for development testing will assuredly have automatically timed spark retard and air injection subsystems. These will probably be simple clockwork devices to change the settings at 1½ minutes after a cold start.

4. The Balgord car is a fluke, a one-of-a-kind effort. It has not been duplicated on other cars.

Well, they must have said the same thing about the Wright brothers. This project was done on a shoestring budget. The total cash outlay for developing a system that works has been less than $50,000—much less than Chrysler spent to tell the world that these standards could not be met. The auto industry claims to have spent over two billion dollars, and their spokesmen say that they have not been able to duplicate these results. Frankly, we do not believe this. We believe that Detroit has developed and tested identical systems and probably others equally as good, but is keeping them behind locked doors. Once again, Detroit is waiting to be forced to take action. Well, this car calls Detroit's bluff. Is Bill Balgord that much smarter than their teams of engineers? He's done the job they said couldn't be done, but were they telling the truth?

6. How do you feel about the proposed stretch-out of the original standards? How does it affect the energy crisis?

There are two stretch-outs. The Senate Public Works Committee is proposing a one-year extension of the 1975 interim standards. I can buy this because these interim '75 standards are tough enough on HC and CO that most cars will have oxidation catalysts.

Unfortunately, the EPA is having second, third and fourth thoughts about NO_x control. They have asked the Congress for a 13-year stretch-out for the meeting of the 0.4 grams per mile. The limit is to be 2.0 from 1977 through 1981 model year, 1.0 from 1982 through 1989 and 0.4 from 1990 onward.

My judgment is that the auto industry will remain with EGR for 49 states through 1976 (California is 2.0 from 1975 onward) when the limit is 3.1 grams per mile. I presume that in 177 they will achieve the 2.0 limit with proportional EGR, fast heat-rise manifolds and pressure-compensated carburetors. Giving the auto industry the benefit of the doubt, we would expect to see such cars suffering a ten percent fuel penalty (compared with 1972 model year cars) through 1976, and getting equal mileage in model years 1977 through 1981. This contrasts with at least a 20 percent economy gain with the Balgord system (perhaps more since the tests indicated 25 to 40 percent improvements). From 1982 onward, the NO_x limit is tight enough that catalysts will be necessary just as on the Balgord system, and there is no fuel loss or benefit.

Therefore we can limit our computation to those cars produced during 1977 through 1981. About ten million cars are made each year, and each one lasts about ten years on average. By 1990, when the last 1981 cars would be disappearing from our roads, these non-Balgord cars would have consumed an extra 94 billion gallons—about half of what we expect to extract from the Alaskan North Slope. Snrely that's worth careful analysis.

Mr. ROGERS. Thank you.

This sounds like a very interesting development. You are saying you have simply used present technology on a 1972 Matador, and have reached 1976 standards?

Mr. BALGORD. That is correct.

Mr. ROGERS. Has anyone checked this other than you?

Mr. BALGORD. Yes. This car has been tested in three laboratories. It has been tested by the New York City Department of Air Resources Laboratory, by the EPA laboratory in Ann Arbor and also by Gould in Cleveland. And the results generally agree quite closely among themselves. I have a copy of the EPA report that I would like to submit for the record.

[The EPA report referred to follows:]

EVALUATION OF THE NEW YORK STATE DUAL-CATALYST VEHICLE

Test and Evaluation Branch, Emission Control Technology Division, Environmental Protection Agency—November 28, 1973

BACKGROUND

Dr. William Balgord of the New York State Department of Environmental Conservation contacted the Emission Control Technology Division to request low mileage evaluation of a dual catalyst control concept. Testing of the vehicle was arranged and conducted in June of 1973. Subsequent to this evaluation the vehicle was returned to New York State personnel for mileage accumulation. After compiling approximately 25,000 miles on the dual catalyst system, Dr. Balgord again brought the vehicle to the EPA Ann Arbor test facility for evaluation.

SYSTEM TESTED

This dual-catalyst employs Gould reduction catalysts (model Gem. 67) for control of oxides of nitrogen and Engelhard oxidation catalysts (model 2B) for control of hydrocarbon and carbon monoxide. The reduction catalysts are located forward of the oxidation catalysts in the exhaust system. To facilitate quick attainment of system operating temperature and good start emission control, two techniques are employed. First, the distributor timing is modulated for cold start. During starting normal ignition timing for the engine is set. Immediately upon engine start up the timing is retarded and employed for about two minutes before switching back to the normal ignition setting. To allow this timing modulation a dual point distributor system is used in conjunction with manual switching. While manual switching was employed in the prototype vehicle, production vehicles would utilize an automatic timed solenoid. The second technique involves start-up modulation of injection air. During the first two minutes of operation following cold start air is injected at the exhaust ports in front of the reduction catalysts. This injection leads to oxidation both in the exhaust manifold and in the reduction catalyst. After two minutes the exhaust port air is shut off and only normal air injection in front of the oxidation catalysts is employed. Again, on the developmental system air switching is accomplished manually but in production this manual function would also be replaced with an automatic timed solenoid.

The system as tested employed conventional carburetion calibrated to give a relatively constant carbon monoxide level of between 2 and 3 percent. Lean excursions of the carburetor have been minimized through careful bench calibration. Since proper system performance depends on operation within this carbon monoxide band, frequent calibration based on barometric pressure (air density) is required. (One planned test at the EPA was canceled due to excessively low barometer.) In production this sensitivity could be alleviated through the use of barometric pressure compensated carburetion techniques.

The vehicle used for this system demonstration was a 1972 American Motors Matador equipped with a 304 CID eight cylinder engine and an automatic transmission. The vehicle was tested at a 3500 pound inertia weight.

MILEAGE ACCUMULATION AND VEHICLE MAINTENANCE

The dual catalyst system was operated by New York State personnel for 25,000 miles over a period of about 5½ months in both city-suburban and highway situation. It is not possible to assess the equivalency of this accumulation procedure with the current certification driving schedule. Lead-free Amoco premium gasoline (as marketed in the eastern United States) was used exclusively for this mileage accumulation. New York State personnel reported that mileage accumulation will continue.

In general, maintenance on the vehicle followed that recommended by American Motors for its 1972 automobiles and did not specifically follow current certification procedures. As previously noted carburetor adjustments were frequently made to facilitate emission testing under varying barometric conditions.

TEST PROGRAM

All testing was performed in accordance with the 1975 Federal emission test procedure as specified in the November 15, 1972, Federal Register (and appropriate subsequent modifications). Testing and vehicle operation required the use of unleaded gasoline.

A total of five emission tests were run at the EPA laboratory in Ann Arbor, Michigan. The first was conducted in June of 1973 when the catalytic system was at low mileage. Early in November of 1973 the vehicle was tested twice after approximately 25,000 miles had been accumulated on the system. During that testing starting problems attributed to poor choke and inadequate driver operation were encountered. The vehicle was returned in mid-November after a comprehensive tuneup for retest. Two additional tests were run at that time. The first of these latter two tests was voided by a CVS operation error.

Fuel economy for the second and third series of tests has been calculated using the carbon balance technique. For comparative purposes the 1972 Federal emission test procedure has also been used to calculate fuel economy.

TEST RESULTS

Table I illustrates the 1975 composite emission results obtained during the EPA testing. Also presented are fuel economy data calculated using the 1972 Federal emission test results and the carbon balance technique.

During tests #2 and #3 the vehicle stalled or false started several times during the cold start. This poor performance stemmed from inadequate choking and driver operation and led to relatively high hydrocarbon emissions.

Test #4 after tuneup was characterized by good starting performance. This test demonstrated emission levels near the 1976 statutory limits.

CONCLUSIONS

1. At low system mileage the New York State dual-calatyst vehicle met the 1975 statutory levels.

2. Excluding tests which were characterized by cold starting problems, after 25,000 miles the dual-catalyst system is still operating near the 1976 statutory levels.

3. Fuel economy measured was 11% poorer than for a comparable 1973 AMC vehicle but only 3% poorer than for a comparable 1974 AMC vehicle. The test vehicle was a converted 1972 AMC vehicle, but no fuel economy data for a comparable unmodified 1972 AMC vehicle is available.

TECHNICAL ASSESSMENT

The New York State dual-catalyst system closely parallels the type of systems reported by Gould and other manufacturers at the EPA hearings early this year. There are no significant technological differences employed by New York State except that the Gould catalyst utilized by New York State does *not* represent the latest generation of Gould catalysts. The vehicle did display good emission control for 25,000 miles of system operation as contrasted to the unfavorable evaluations reported earlier to EPA by manufacturers.

After meting with New York State personnel and analyzing the data presented in this report, the EPA technical staff still considers their previous assessment of the dual-catalyst approach as valid. Relatively tight control of air-fuel ratio is required mandating the use of advanced carburetion with air density compensation. The latest test data as reported here indicates that after 25,000 miles of operation the NO_x control has deteriorated and is near the statutory limit. Previous information available concerning the Gould system would suggest that rapid deterioration of NO_x control after 25,000 miles would also be expected to occur for the New York State system. New York State personnel plan to continue mileage accumulation and subsequent data would be useful for verifying the deterioration rate.

While the successful demonstration of 25,000 miles of emission control at the 1976 statutory standards indicates the importance and potential of continuing research and development of the dual-catalyst approach, a single successful test does not indicate that the dual-catalyst approach is ready for implementation on new vehicle production. In his July 30, 1973, decision the Administrator concluded that ". . . although the Gould catalyst has shown by far the best durability results of any (reduction) catalyst to date, more work on matching the catalyst to the engine and on improved fuel metering, accompanied by extensive durability testing, will be required before it will be ready for widespread vehicle use." The data obtained through the testing of the New York State vehicle does not materially change the data base from which the Administrator drew his July 30 conclusion.

TABLE I.—NEW YORK STATE CAR, ANN ARBOR EPA TESTING

Date	Test No.	Odometer mileage	1975 FTP HC	1975 FTP CO	1975 FTP CO_2	1975 FTP NO_x	1972 FTP, miles per gallon
June 6, 1973	1	29,039	0.33	2.99		0.11	
Nov. 1, 1973	2	49,035	1.02	3.37	746.5	.40	11.2
Nov. 2, 1973	3	49,048	.68	3.22	731.3	.32	11.4
Nov. 23, 1973	4	49,175	.37	1.67	751.4	.47	11.2
1976 statutory standards			.41	3.4		.40	
Average 3,500 lb 1973 vehicle							13.9
1973 AMC 3,500 lb 304 CID (1 vehicle)							12.6
1974 AMC 3,500 lb 304 CID (2 vehicles)							11.6

Mr. ROGERS. But in all three instances, you do meet the standards?

Mr. BALGORD. Yes; the standards have been met. We would have to concede, like everything else, that there is a certain statistical aspect to them. And we feel that in particular the standard relative to the NO_x emission is the important one, that in the past other catalyst companies—and for that matter, even auto companies—have demonstrated the ability of systems to control hydrocarbons and carbon monoxide. And the crucial thing we felt, at this point, was the nitrogen oxides.

Now, a statistical analysis done on the data obtained from low mileage from 2,500 miles through to 25,000 miles indicates that we have in fact, met the statutory standard for nitrogen oxides.

Mr. ROGERS. That is very impressive.

Mr. Satterfield.

Mr. SATTERFIELD. Thank you, Mr. Chairman.

I think your testimony is interesting and impressive, and I have only one question. What is the impact of your device upon the availability of gasoline? Do you use nonleaded gas?

Mr. BALGORD. Yes; we have used nonleaded gas with this vehicle since the inception of the propect; however, we would like to comment relative to the fuel economy.

The first thing is that Mr. Stork of the EPA yesterday commented that the car showed an 11-percent decrease in fuel economy. We feel looking at the data obtained from a number of laboratories, as well as from EPA, that there really is not very much difference between fuel economy for this vehicle and the original 1972 model car.

Now, keeping in mind this test is done with a preponderance of low-speed driving, the average speed during the LA-4 test, which the EPA uses, is about 18 or 19 miles per hour. We have also data taken over the road, real world in-use data, which indicates a substantial increase in fuel economy.

And we feel that conservatively this represents perhaps 20 percent. It may be higher. It may be as high as 25 or 30 percent better. I can give you an example.

About a month ago, before the inception of the 50-mile-an-hour speed limit that has been requested, we ran off about 800 miles of driving in five segments. The average speed at that time was 68 miles per hour, and the fuel economies for these five determinations were as low as 17½ and as high as 20 miles per gallon.

Now, I would offer here that there are not many cars of comparable size and engine type which could boast of such fuel economy at relatively high speed today.

Mr. SATTERFIELD. That was a relatively constant high rate of speed; was it not?

Mr. BALGORD. Yes. For the most part, it was averaging that speed, Mr. Satterfield. But we have also records called tachographs, which provide a continuous record of the speed of the vehicle versus the time it is in use. And it is surprising, or at least it was surprising to me the first time, the amount of detail or the amount of variation of speed which shows up.

We think—well, that we are driving at constant speed and we really are not.

Mr. SATTERFIELD. Would you think your speeds anywhere meet the profile of normal motor vehicle operation in an urban area, or a rural area, or in a suburban area?

Mr. BALGORD. I think to the extent the overall use of the vehicle has had a pretty good mix of different driving. We estimate about 40 percent of our driving has been city-suburban, about 20 percent normal highway, and about 40 percent on the turnpike or the New York State Throughway.

Mr. SATTERFIELD. Thank you very much.

Mr. ROGERS. Dr. Carter.

Mr. CARTER. It seems to me like you have a very marketable product, something that would surely do something for the American public.

Have you tried to sell this? Have you made an effort to sell it to any of the automobile manufacturers?

Mr. BALGORD. No, sir. I think what the submission says here is that we have components that were provided from a number of sources, those being American Motors, Englehard Industries, Maremont, and Gould. And, although perhaps we have put this together in a little bit different way than other people have done before, that basically this is available technology.

And as a matter of fact, we would offer that this is probably last year's technology; and were we to set a car up today, we would probably be able to take advantage of these newer developments and realize even better levels of performance in terms of emission control and fuel economy.

Mr. CARTER. According to these figures here, you have already reached the 1975 standards, or quite a bit below it—or 1976.

Mr. KETCHAM. Mr. Carter, that is correct. I think you are misreading our reason for being here though. We have come to tell you about the car, and to tell you that we disagree with H.R. 11475.

Mr. Satterfield, you just asked what the impact of the Balgord car would be as compared to either current technology. I will give you two examples. I did an evaluation of adopting the Balgord car in lieu of H.R. 11475, and the results come out to a savings in fuel of about 5.1 billion gallons of gasoline annually, just by the impact of the 3 years of producing cars, 1975, 1976 and 1977, that is averaged over a 12-year period.

Mr. SATTERFIELD. May I ask whether you cranked into there the loss that is occasioned by producing nonleaded gasoline?

Mr. KETCHAM. No; I did not. Reduction of nonleaded gasoline would reduce that figure by some few percent.

Mr. SATTERFIELD. You are just talking about the savings out of the tank of the car?

Mr. KETCHAM. That would be the savings gained in adopting the dual-bed catalyst systems. If you take that as 100 percent of total savings, the refinery costs for just nonleaded gasoline are a very small percentage of that. In other words, the cost to get lead-free gasoline for use in this car is a very small cost in comparison to the savings that you make from adopting the system.

Now, another example that I ran, or the calculation that I ran was to relate this to existing or proposed Senate regulations of extending for 1 year the 1975 interim standards, combined with adopting the EPA long-term NO_x regulations of going to 2 grams per mile for the model year—I believe—1977 through 1981. Again we are comparing this action against adopting the Balgord system for 1976 model cars.

So assuming the Balgord system is adopted in 1976 you would see a savings of some 6.2 billion gallons a year averaged over 15 years. That comes to close to 94 billion gallons of gasoline. That is about half of what is projected to be available from the Alaskan North Slope oil fields.

Mr. CARTER. What is the cost of these different mechanisms put on the car?

Mr. BALGORD. I believe we heard testimony earlier today from the Gould people that the——

Mr. CARTER. In this particular instance is what I——

Mr. ROGERS. In other words, what did it cost you?

Mr. BALGORD. What did we spend on the project? We estimate about $50,000, but what it would cost to do this in the hands of the industry is quite a different thing. I mean, they have at their fingertips all of the advantage of mass production.

And I think that—you want to know what it costs to do this car or——

Mr. CARTER. No. What would it cost on a mass produced basis?

Mr. BALGORD. On a mass produced basis, I would go along with what Gould said, probably a $60 to $65 addition to the sticker price.

Mr. CARTER. Thank you.

Mr. ROGERS. Mr. Symington.

Mr. SYMINGTON. Thank you, Mr. Chairman.

Let us see now, Dr. Balgord. This car—you chose a Matador. Was there any particular reason for that?

Mr. BALGORD. We actually had rather little choice available to us The history of this is that we asked the State for a car to carry out these experiments, and that year, or the year before, the State had entered into a contract with American Motors for this style of vehicle, and that was continued actually again in 1972 and 1973.

So these were the vehicles available to us.

Mr. SYMINGTON. The Matador, I guess, is a middle-sized, middle-priced car. Would that be true? It is fairly heavy.

Mr. BALGORD. The car—I think the curb weight is something just below 3,500 pounds. However, I would add that in the way we have been operating the car with the equipment that we have on board, test equipment and also a so-called fuel cell—this is just an oversized gasoline tank that has precautions against fire—that the weight in this condition is probably more like 4,100 pounds.

Mr. SYMINGTON. All right.

Well, almost all of the witnesses have testified that the lighter the car, the greater the fuel economy, and in fact even under their systems, the more effective the system itself. Would that be true with your——

Mr. BALGORD. With this system?

Mr. SYMINGTON. With your system.

Mr. BALGORD. Most certainly, it would; yes, sir.

Mr. SYMINGTON. In your kind of simplified description of the difference, you talk about altering the actual combustion chemistry with changes in the carburetion and spark timing. It sounds almost simple, but it is not really, is it?

At least, it cost you a great deal of money to develop that.

Mr. BALGORD. Well, I think that we would say once one knows what to do, that it can be duplicated beyond that point for relatively small cost.

Mr. SYMINGTON. Is this something that could be retrofitted on existing cars?

Mr. BALGORD. Yes, it could be. As a matter of fact, in a very real sense, this was a retrofit. I mean the car was—yes.

Mr. SYMINGTON. You recall Mr. Cole testified that it would be very easy to remove all of the emission controls from existing cars. This was something that Mr. Train disputed in his testimony.

But would you say that it would be just as easy to add your system to today's cars as it would be to remove the one that is already there?

Mr. BALGORD. Unfortunately, probably not.

Mr. SYMINGTON. Not quite.

Mr. BALGORD. There are, of course, different categories of the things that can be done relatively easily versus things which are more difficult. The second category are things like changing the compression ratios or the valve timing. Changing valve timing involves changing the cams, and that is a fairly major operation.

Excuse me. Would you like to comment on the aspects of retrofit as it might apply to taxis?

Mr. KETCHAM. Yes. We in fact in the city of New York have adopted the strategy of retrofitting some specialized vehicles in our State transportation controls plan. One of those is to retrofit our taxi fleet so that they meet certain emission specifications.

At this point in time, we are talking about the interim 1975 standards for taxicabs for early 1974. However, we would like to go ahead with the system similar to what Bill has developed, and retrofit those to taxicabs.

We have with EPA funding been exploring retrofitting of intermediate and heavy-duty trucks within the city, including the use of catalytic devices. And we are going through a process now of selecting various devices which may or may not work, and determining the impact of those devices.

Mr. SYMINGTON. I thank you very much for your testimony.

Thank you, Mr. Chairman.

Mr. ROGERS. Mr. Heinz.

Mr. HEINZ. Thank you, Mr. Chairman.

I want to thank the witnesses, Dr. Balgord and the others, for some very provocative testimony. And I have no questions at this time.

Mr. ROGERS. Mr. Hudnut.

Mr. HUDNUT. Just one question; thank you, Mr. Chairman.

Is all of the equipment that you retrofitted onto the Matador equipment that is already being manufactured, or did you invent some of it; and if so, do you have patents on it?

Mr. BALGORD. The answer to the last of those is no. What we have done, with assistance from the corporations we already named, is to package available technology. We have no patents on this. I do not think there would be any. The other question was, are these components manufactured. I think that they all are, except perhaps the nitrogen oxide catalyst provided by Gould.

But I think they (Gould) also would be in a position to provide these in a fairly good volume on a relatively short notice. So that it would not be a difficult thing to conceive of a project involving perhaps as many as 50 vehicles to demonstrate their operation on a fleet.

Mr. ROGERS. Well, I think we ought to bring this to EPA's attention. Let us see what they are going to do about it.

Mr. HUDNUT. Right.

I yield to the chairman to pursue the point.

Mr. ROGERS. Don't you agree?

Mr. HUDNUT. Yes.

Mr. ROGERS. I think we should, and the committee will.

Mr. KETCHAM. I would like to respond to Mr. Hudnut's question.

Mr. ROGERS. Certainly.

Mr. KETCHAM. I think what is unique here is that Dr. Balgord has taken a set of existing hardware, and has been able to combine it in a way that he has been able to meet the Clean Air Act standards, like nobody else has been able to do. This car has operated 25,000 very hard miles. He has been very careful to use Amoco lead-free gasoline in it.

But it meets those standards at that mileage limit, and EPA allows you to replace those catalyst elements at that point.

So I think that what we are trying to show—what we are trying to tell you—is that maybe the job can be done. It has been done on a shoestring budget. You might want to compare Balgord's budget to what Chrysler spent for two full-page advertisements in the New York Times to tell how it cannot be done. That is about the size of the entire budget that he has had available to meet these standards.

Mr. HUDNUT. Well, Mr. Chairman, the thing that confuses me is that we have been here all afternoon hearing about the difficulty of the problem, how these automotive giants have spent years and untold millions striving toward what appear to be unattainable goals; and here we have three very intelligent young men who seem to document the assertion that the automobile industry really does not want to get there very fast. And that is why they are asking us to delay and defer.

Really, if you take all of the know-how in Detroit and assemble it all, and put it in production; it seems to me the job can get done. And I disagree with what was said earlier. I do not think the American people would be disinclined to pay $65 more for a car if it were a car that would achieve this kind of emission control.

Mr. ROGERS. And also, I would think it would be helpful if you could add what your mileage has been; so that we can pursue that.

[The fuel economy data requested is provided in the Status Report dated December 3. 1973, p. 344, this hearing.]

Mr. CARTER. Mr. Chairman.

Mr. ROGERS. Yes.

Mr. CARTER. I want to thank these gentlemen. I understand they came down at their own expense.

Mr. ROGERS. Their own expense, and this is most important, we are most grateful.

Mr. CARTER. I thank them for coming, and for their presentation, which I think was very good.

Mr. ROGERS. We are very grateful to you, and we plan to follow this up to see what can be done.

Mr. KETCHUM. Thank you, Mr. Chairman.

Mr. BALGORD. Thank you, Mr. Chairman.

Mr. ROGERS. We are grateful for you being here.

Our next witness for, I understand, a very short statement is Mayor C. W. Thomas, Stillwater, Okla.

Thank you.

Mr. Mayor, you can take the stand here, and if you will identify yourself, we will be very pleased to receive your testimony. Dr. Carter was very anxious to have the committee hear your statement, and we are most pleased to have you.

Mr. CARTER. Mr. Chairman, if you would yield on this?

Mr. ROGERS. Certainly.

Mr. CARTER. We are going to see the other side of the coin, from the dealer's side; and I happen to know several dealers and the trials they are undergoing at the present time. And this is why I thought we should hear him.

Mr. ROGERS. Certainly. I think this will be very helpful.

STATEMENT OF C. W. THOMAS, MAYOR, CITY OF STILLWATER, OKLA.

Mr. THOMAS. Mr. Chairman, Congressmen, I am C. W. (Bill) Thomas, the mayor of the city of Stillwater. I am the vice chairman of the Ford Dealer Organization of our country. I serve as a vice chairman of the Oklahoma Good Roads Association, and was the recipient of the Saturday Evening Post award in 1968.

I am not here in an official capacity. I was not invited here by Ford Motor Co. or anybody else. I am en route to have some bonds rated at Standard & Poor's tomorrow on a new hospital we are building.

But my concern is I know you gentlemen are hearing the finest talent in the country relative to the engineering emission problems and how to resolve them. But we as automobile dealers and the consumer, with which we deal on a day-to-day basis, have a catastrophic problem ahead of us as I see it, and a part of which is something that perhaps you might be able to do something about.

I am afraid that we, the public and automobile dealers are caught between these industrial giants. And when I say that I see General Motors on one side. I see Ford, Chrysler, and American Motors on the other. I congratulate you on your laborious efforts here to try to secure the facts. But I am not sure that this is not a power play with the consumer as the man at the low end of the totem pole. I wonder what commitments have been made for a Wankel engine, requiring catalysts and perhaps if this is going to afford a material marketing gain for one giant over another giant.

But we, as a consumer, and we, as an automobile dealer, are facing the public on a daily basis; we do not know whether you realize this or not, but when one walks into an automobile dealership, or if you stand around a dealership showroom floor you would hear an awful lot of people giving you men right here a lot of unfavorable compliments that perhaps you are not entitled to.

Mr. ROGERS. Well, we hear that not only from automobile companies, I might say.

Mr. THOMAS. Well, as a mayor, I am even a little closer to the local level.

Mr. ROGERS. Then you are aware of this, too.

Mr. THOMAS. That is correct. The concern that we have—a part of which takes place right in our dealerships. Now, over the past few years perhaps it should be recognized that we, as a consumer and as an automobile dealer, have paid a large price to date for cleaning up the air. And that does not mean that we do not want to continue to clean the air up; but I would call to your attention that we have a tremendous problem from the standpoint of drivability of our product today.

I served as a chairman of the dealer council subcommittee for the service managers of the Ford organization last year, and I listened to these men from all over the country; and one of the top problems that we had was drivability, and a part of this stems from the adjustments on the carburetors and the timing of the automobile that are limited at this time because of emission problems that we have.

Now, we, some 23,000 automobile dealers across the country, who serve as a buffer between the public and you and the public and the manufacturer. As an automobile dealer perhaps in relating to some of these concerns I would like to call them to your attention.

There were some statements made here earlier that I really do not know to be false but I am real concerned about their creditability. I have reason to question or doubt some of the things that were so stated here. For example, Mr. Cole I know travels in circles in which I do not travel; but I also would have certain reason to disbelieve some of the information that he gave you relating to the oil company servicing problems, for I own several service stations. One of them is closed now because I cannot get gasoline for it; another has gasoline about two-thirds of the time. I have Texaco stations and we have a Standard station; and they could not accommodate lead-free gas without putting in new tanks, and bringing in new equipment—contrary to what was testified here a little earlier this afternoon.

I have tremendous concern over what is going to happen—you men perhaps at this level of government think of us as out in the boondocks, but we do not feel that way. I have real concern about how we are going to furnish gasoline for the automobiles we have. You are talking about compounding our problems right now if you go to the 1975 level at this particular time.

Now, what happens when you drive out in western Kansas, Oklahoma, South Dakota, or the smaller towns across the country? As I understand the law now, the requirement is that if a service station sells less than 200,000 gallons of gas a year, Congress is not going to impose upon them a need to change over the tank and the pumps and all this. Well, if this is the case, what happens to you when you travel and what happens to the people that live in the rural areas? I think that you must give them some consideration and react responsibly to the traveler.

The cost of the catalysts—I think the manufacturer can pretty well document—and if it is economically justified from the standpoint of realistic health standards. I think the catalyst is justified. But I really do not think that anyone is prepared at this time to meet the multifaceted problems for example at this particular time, as an automobile dealer, I know of absolutely no means why which I could test or determine what pollutants are emitted on any automobile that I service from the standpoint of the emission concerns that we are talking about right now.

And I do not know, though perhaps they have test equipment in California, but in our part of the country we have none.

I am talking about a couple of the problems of some 23,000 automobile dealers in the country. What about the literally tens of thousands of other people that are in the transportation business? You see, one-seventh of all the people in the United States are involved in the transportation system. At this time increased emission standards could have a catastrophic impact upon the automobile dealer, the public, and the service station in trying to secure transportation, maintenance, and service the system.

Now, as we go into what could be a downturn in the numbers of jobs, as the economy turns down, as it perhaps may, because in spite of what these gentlemen report about production, I am getting like one-third of the number of automobiles for December that I was afforded a year ago this time.

Reports are that this is because the big car is not selling, but the truth is they cannot produce the small cars in the quantities necessary to take care of our country's needs, and they are plagued with material shortages.

Maybe I am taking too much time, and I will apologize for it. The hour is late, and I recognize that.

Mr. Rogers. And we do have additional witnesses, yet we do want to hear you. However, it would be helpful if you could conclude as soon as possible.

Mr. Thomas. I would like to suggest that you give serious consideration to the extension of the 1974 standards. And I do not say this on behalf of Ford Motor Co., but on behalf of the consumer who I deal with and those of us that serve the consuming public in the automotive trade.

I am sorely concerned about these new standards and the effect of implementation. And with this, gentlemen, I thank you very much for affording the opportunity for participating.

Mr. Rogers. Thank you for being here, Mr. Mayor. We appreciate your help to the committee.

Dr. Carter.

Mr. Carter. Yes, sir. What about the new interlock seatbelts?

Mr. Thomas. Dr. Carter, I hate to tell you this, and perhaps you do not want to know this, but I think a few years from now if it continues the way it is, Congress will probably get credit for changing the anatomy of the American woman, because the left mammary gland is going to have a real hard time surviving.

Let me go a little further. I think really that this has lowered the safety standards in spite of what has been intended, because so many people are disconnecting the unit, and now they no longer use the lap belt because they have this—well, I do not want to say what kind of an unfortunate kind of harness Congress is to try to force them into.

Mr. CARTER. What does the general public think about it?

Mr. THOMAS. They just hate it.

Mr. CARTER. Well, think about all the different things we have put on the car since 1971.

Mr. THOMAS. Well, this just multiplies the problem, Dr. Carter, and this is the thing that so concerns me. The public giving you credit for the chaos, and really, I think this is terribly concerning; I could relate a District Judge who came to me and said Bill, get that thing off of my new car. I cannot drive the damn thing, and my wife won't.

Mr. CARTER. To tell you the truth, I had to sell one because of the poor drivability.

Mr. THOMAS. This judge's wife will not drive a 1974 LTD, in that she would not harness up, they have retained the old car that she can drive it. He requested I disconnect the seatbelt interlock and legally I cannot.

Mr. ROGERS. That is right.

Mr. Symington.

Mr. SYMINGTON. No questions.

Mr. THOMAS. You play good football, Mr. Symington.

Mr. ROGERS. Mr. Heinz.

Mr. HEINZ. Mr. Chairman, thank you. And I will not ask if she went out and bought a GM product after she sold the LTD. I pass.

Mr. ROGERS. Mr. Hudnut.

Mr. HUDNUT. No thank you, Mr. Chairman.

Mr. ROGERS. Thank you, and we are most grateful for your being here.

Mr. THOMAS. Thank you very much.

Mr. ROGERS. Our next witness is Dr. John B. Heywood, a consultant to the National Academy of Sciences, director of the Sloan Automotive Laboratory, the Massachuetts Institute of Technology, Cambridge, Mass. We are sorry to have held you this late, and we apologize. Your statement will be made a part of the record in full. And if you could give us the points very quickly, it would be helpful.

STATEMENT OF JOHN B. HEYWOOD, ASSOCIATE PROFESSOR AND DIRECTOR, SLOAN AUTOMOTIVE LABORATORY, DEPARTMENT OF MECHANICAL ENGINEERING, MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Mr. HEYWOOD. My name is John B. Heywood. I am an associate professor and director of the Sloan Automotive Laboratory in the Department of Mechanical Engineering at MIT. I am a consultant to the National Academy of Sciences Committee on Motor Vehicles, and for the past 2 years have been chairman of their Panel on Emission Control Systems for Spark-Ignition Engines. My research for the past 5 years has been on emissions and performance characteristics of different automotive engines. In addition, I am a member of an interdisciplinary group of faculty at Columbia Law School, Harvard, and MIT working on a National Science Foundation supported study on regulating the impact of the automobile on the environment.

I want to discuss briefly, two questions. First, what emission standards are required over the next 5 years to continue the downward trend in average emissions from the in-use automobile population? Second, are there engines and emission control technologies which can meet these standards with improved fuel economy relative to current new vehicles?

The rate at which average emissions from the in-use automobile population decreases depends on both the new car emission standards and the dynamics of the vehicle population. This latter factor is often ignored. It is most important because it is the difference in emissions of the old dirty car scrapped from the car population and the emission of the new car which replaces it which determines the change in aggregates emissions.

In appendix I attached to my statement, I present results of calculations which show the effect of different new-car emission standards on aggregate emissions 1970–90. For hydrocarbons and carbon monoxide, continuation of the 1975 interim standards for up to 5 years followed by the original 1975 standards in the 1980 model year, gives almost as rapid a reduction in emissions as does the currently legislated schedule.

For example, a comparison of CO emissions from a typical urban automobile population in 1980 shows that, under the original schedule, the emission rate would be 76 percent below the maximum 1967 rate. With a 5-year extension of the 1975 interim standards, the emission rate would be 64 percent below the maximum 1967 rate. For shorter extensions, and stricter interim standards, of course, the differences in the reduction achieved would be less. For hydrocarbons the difference between these schedules is smaller.

In summary, provided the interim HC and CO standards are below the current 1974 standard, and provided the extension is less than 5 years, the slippage from the results intended by the 1970 Clear Air Amendments is small. The notion that a few years' delay in implementing the original 1975 standards results in significant deterioration in air quality is not valid. Much more important at this stage is the need to lay out a 5-year schedule of emission standards so the current uncertainty can be removed, and a more rational development of the appropriate technology can take place.

In the meantime, we need to carry out an extensive investigation of how effective the current automobile emission control program has been and whether it has had the intended effect on air quality. The evaluations to date are not adequate. We also need much more extensive analysis to determine what automobile emission standards should be in the early 1980's. The analytic basis for the original 1975–76 standards is not sufficient for this purpose.

As an example of our lack of understanding, evaporative automobile HC emissions were thought to be almost completely controlled. As described in appendix II recent surveillance data suggest evaporative HC emissions from 1971 and subsequent model vehicles in use are not adequately controlled and are comparable to exhaust emission levels.

The status of NO_x control is different. The current standard of 3 grams/mile is a 30-percent reduction from average 1973 levels. Thus the degree of control achieved for NO_x to date is significantly less than has been achieved for hydrocarbons and CO. The most extensive study of the NO_x emissions reduction required to meet the NO_x air quality standards[1] by a National Academy of Sciences panel indicates an NO_x emission standard of about 1.5 grams per mile is required. Again, the dynamics of the vehicle turnover are such that these levels do not need to be imposed immediately, but can be phased in over several years.

The second issue I want to raise is that while in the past emission reductions have been accompanied by deteriorating fuel economy, there are emission control systems now being developed for spark-ignition engines which will achieve lower emissions with better fuel economy than current new vehicle values.

I have recently completed a study on "The Relationship Between Fuel Economy and Emission Control for Automotive I.C. Engines" for the Department of Transportation, which I attach as appendix III. I made approximate estimates for several different control systems of emission levels achievable in actual use, and the vehicle fuel economy. And the general conclusions are as follows:

For each engine-emission control system combination, as emission levels go down, so fuel economy deteriorates. While the NO_x emission level is the most important factor, the hydrocarbon emission level is also an important consideration. But some of these engine-control system combinations can achieve better fuel economy than others, at the same emission levels. Alternatively, some achieve lower emission levels than others at the same fuel economy.

In my judgment there are three promising directions for future developments, each on a different time scale. By significantly improving the fuel-air mixture preparation in the current conventional engine and by using high-energy long-duration-spark ignition systems, reductions in emission levels below current new vehicle levels and improvements in fuel economy and drivability can be obtained. Experimental systems of this type are now being developed. These should meet emission levels of 1.5 grams per mile hydrocarbons, 15 grams per mile CO, and 2 grams per mile NO_x. These systems could be developed within 3 years.

On a longer time scale, 3 to 6 years, engine concepts like the Honda dual-carburetor divided-chamber engine offer lower hydrocarbon and CO emissions without any further deterioration in fuel economy. The emission-control potential appears to be about 5 grams per mile hydrocarbons, 5 grams per mile CO, and 1.5 to 2 grams per mile NO_x at fuel economy levels comparable to or better than current new vehicles.

Finally, there are a number of fuel-injected stratified-charge engine concepts on a 6- to 10-year time scale. These spark-ignition engines are closest to a diesel. They offer a significant improvement in fuel economy, about 25 percent compared to current new vehicles. They have the potential for NO_x emission levels below 1 gram per mile.

The potential is clearly there for improvements in both emissions and fuel economy compared with 1974 levels.

Thank you.

[Testimony resumes on p. 379.]

[Appendix I, II, and III, referred to, follow:]

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[1] "A Critique of the 1975–76 Federal Automobile Emission Standards for Hydrocarbons and Oxides of Nitrogen," Panel on Emission Standards and Panel on Atmospheric Chemistry, Committee on Motor Vehicle Emissions, National Academy of Sciences.

APPENDIX I: CALCULATIONS OF AGGREGATE AUTOMOTIVE EMISSIONS

The in-use automibile population is a mix of different age vehicles. The aggregate emissions from the total population depends on the emission levels of each model year, the vehicle age distribution and the number of miles per year driven by vehicles of different ages.

The following two graphs present result obtained by calculations which take account of all these factors, and of growth in the vehicle population. Different emission standards are assumed for 1975 and subsequent model year vehicles and aggregate emissions are projected into the future.

Figure 1 shows urban automotive hydrocarbon emission rates for 1960–1990. Four cases are shown: (1) continuation of 1974 emission standards, (2) continuation of 1975 interim standard (1.5 g/mile), (3) current schedule (1.5 g/mile in 1975 and 0.41 g/mile in 1976 and subsequent model years), (4) 1975 interim standard for five years followed by 0.41 g/mile in 1980 and subsequent model years.

Figure 2 shows urban automotive carbon monoxide emission rates for 1960–1990. Again four cases are shown: (1) continuation of 1974 emission standards, (2) continuation of 1975 interim standard (15 g/mile), (3) current schedule (15 g/mile in 1975 and 3.4 g/mile in 1976 and subsequent model years), (4) 1975 interim standard for five years followed by 3.4 g/mile in 1980 and subsequent model years.

The reason aggregate emissions are not especially sensitive to new car emission standards is explained by the following example. In 1976, the average vehicle emission rate for CO will be about 30 grams/mile. The dirtier older cars which are scrapped from the vehicle population have emissions of about 80 grams/mile. It is the difference in emissions between the dirty older car, and the clean new car which replaces it which is the important number. Since both 15 and 3.4 g/mile are much less than 80 g/mile, these two alterantive emission standards for the 1976–1979 period give almost the same emissions reduction rate.

Of course, in the late 1970's and early 1980's, the older cars in the car population will have become cleaner. New car emission levels may then need to be further reduced.

FIGURE 1

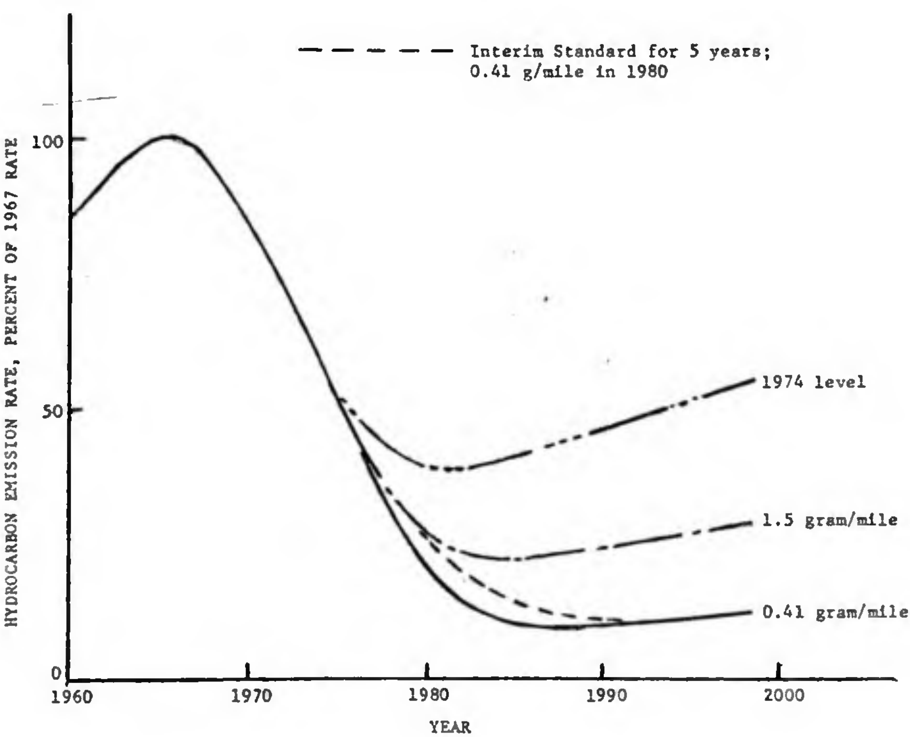
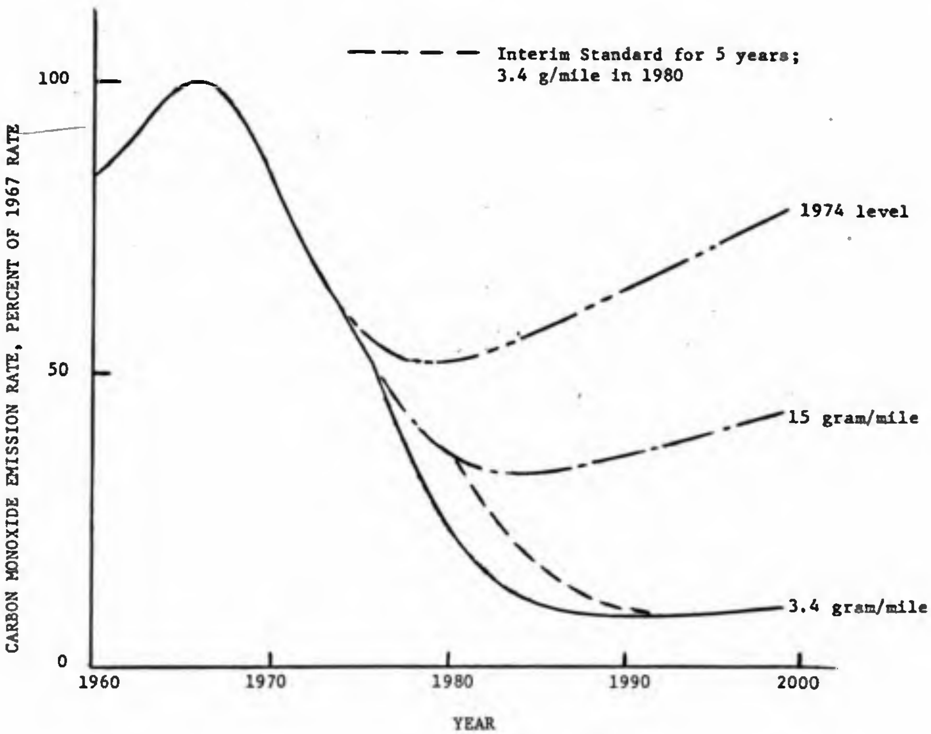


FIGURE 2



APPENDIX II: A PRELIMINARY ASSESSMENT OF AUTOMOTIVE EVAPORATIVE HYDROCARBON EMISSIONS

(John B. Heywood, Department of Mechanical Engineering, Massachusetts Institute of Technology, Cambridge, Mass.—October 29, 1973)

SUMMARY

Recent surveillance data show that automobile evaporative hydrocarbon emissions from vehicles with evaporative emission controls may be much higher than has been previously assumed. This preliminary assessment shows that 1972–74 model year vehicles may have comparable evaporative and exhaust HC emission levels, when expressed in grams per vehicle mile. Since the 1976 HC standard is for exhaust HC alone, it follows that the anticipated reduction in total HC emissions may well not be realized in practice.

Automobile fuel evaporative losses have been known for some time to be an important source of hydrocarbon emissions in addition to exhaust hydrocarbon emissions. There are two distinct sources of evaporative emissions from vehicles, the fuel tank and the carburetor system. The fuel tank warms up every day as ambient temperatures increase from an early morning low to a mid-afternoon high. As a result of expansion of the air-fuel vapor mixture in a partially filled fuel tank, gasoline vapor is expelled from the tank into the atmosphere. These evaporative losses are termed "diurnal breathing losses." As the vehicle is driven along the road, the fuel in the tank is heated, and a similar expulsion of gasoline vapor occurs. These are termed "running losses." Finally, after the engine is shut down at the end of a trip, there are several openings for fuel vapor leaks from the carburetor system (for example, through vents in the carburetor, and clearances around the throttle and choke shafts). Heat from the engine block evaporates the liquid fuel in the carburetor float bowl and forces it out into the atmosphere. These are termed "hot soak losses."

A test procedure to measure these losses has been developed. The vehicle is stood at ambient conditions for 12 hours to ensure the engine has completely cooled down. Cooled fuel is placed in the tank. The fuel is then heated and the diurnal evaporative emissions are collected as the fuel temperature increases from 60°F to 84°F in one hour. The vehicle is then driven through the Federal CVS Emissions Test Driving Cycle (a 7.5 mile drive) and the engine is shut off. "Running" and "hot soak" evaporative losses are measured during the drive and the one hour period following engine shut down. The test thus measures the grams of HC evaporated per day from the fuel tank (diurnal losses), and the grams of evaporative HC lost from the tank during an average urban trip, and from the carburetor during the subsequent engine shut down period following an average trip (running and hot soak losses). An appropriate formula for estimating evaportive HC emissions in grams per vehicle mile is thus:

(evaporative HC emissions in grams per mile) =
(diurnal loss in grams per test) / (miles per day)
+ (running and hot soak losses in grams per test) / (miles per trip)

Suitable average values for miles per day and miles per trip are 27 and 7.5 respectively.

Two different procedures for collecting and measuring evaporative HC emissions have been developed. In the procedure used by the Federal Government for certification of evaporative emission control systems,[1] carbon canisters to trap the gasoline vapor emissions are connected to the fuel tank vents and to the carburetor external vent. At the end of the test the weight of fuel vapor absorbed in these charcoal traps is measured. The second procedure, the SHED (Sealed Housing for Exaporative Determinations) technique,[2] is more comprehensive. The vehicle is enclosed in a sealed enclosure throughout the test and the HC concentration in the sealed enclosure at the end of the test is used to determine the mass of HC evaporative emissions. Federal certification measurements of evaporative emissions using the canister technique are generally considerably lower than emissions as measured by the SHED techinque. The reason is presumed to be that the SHED technique measures losses from the entire fuel system including gasket and throttle shaft leakages. These leakages are not all trapped by the canister technique.

Evaporative HC emissions from pre-1971 model year vehicles (i.e. those without evaporative emissions controls) have been assumed to be 3 grams/mile. This number was derived by the National Air Pollution Control Administration in the Department of Health, Education and Welfare[3] from a General Motors study.[4] The GM study used the SHED technique to determine average evaporative HC losses from 55 vehicles to be about 37 grams per evaporative emission test (grams/test), which was estimated to correspond to 78 grams per day. This estimate is substantiated by the results of a recent EPA surveillance study[5] which measured evaporative HC emissions from 95 pre-evaporative emission control vehicles in Los Angeles using the SHED technique. Average evaporative emissions were 26 grams/test diurnal losses, and 15 grams/test running and hot soak losses. Using the equation already presented for conversion of these gram/test values to grams per vehicle mile, yields 2.9 grams/mile is in close agreement with the earlier NAPCA 3 grams/mile estimate. An evaporative emissions standard of 6 grams/test was introduced in model year 1971. The evaporative emission control systems introduced by the auto manufacturers met this standard easily, when tested with the Federal Certification Test Procedure (the charcoal canister technique). As a result, the standard was lowered to 2 grams/test the following year which was again met during certification. It was therefore assumed that, in 1971 and subsequent model year vehicles, evaporative HC emissions in actual use were essentially completely controlled.

The evaporative HC emissions results obtained in the recent EPA surveillance study[5] with vehicles with evaporative controls suggest that this conclusion is not warranted. In this study, 31 1970 and 1971 model year vehicles were tested in Los Angeles and 20 1971 model year vehicles in Denver using the SHED technique. The results, and the conversion to evaporative HC in grams/mile are given

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[1] "Control of Air Pollution from New Motor Vehicles and New Motor Vehicle Engines," Federal Register, Vol. 31, No. 221. Part II, November 15, 1972.

[2] SAE Procedure J171, "Sealed Housing for Evaporative Determinations (SHED) Technique."

[3] Kramer, R. L., and Cernansky, N. P., "Motor Vehicle Emission Rates," U.S. Dept. HEW, National Air Pollution Control Administration, Office of Criteria and Standards Report, August 15, 1970.

[4] Nelson, E. E. "Hydrocarbon Control for Los Angeles by Reducing Gasoline Volatility," SAE paper 690087, in Vehicle Emissions, Part III, pp. 775–801, SAE, 1971.

[5] "Automobile Exhaust Emission Surveillance, a Summary," EPA Report APTD–1544, prepared by Calspan Corp. under Contract No. 68–01–0435, May 1973.

in Table 1. These data indicate that in Los Angeles evaporative HC emissions have only been reduced by about 30 percent by evaporative emissions controls. In Denver evaporative HC emissions are substantially higher (by a factor of three), presumably due to the lower atmospheric pressure and the different gasoline composition used in the Rocky Mountains. Note that evaporative HC losses of 2.1 grams/mile and 6.4 grams/mile correspond to about a 1 and 3 percent fuel economy loss, respectively, at 13 miles per U.S. gallon.

While these data are limited (they were obtained with tests on 51 cars in two locations), they nonetheless raise a very important issue. These results suggest that vehicles which are supposed to have 95 percent effective evaporative emission controls, have comparable exhaust and evaporative HC emissions in actual use when both are expressed in grams/mile. Table 2 gives exhaust HC emission estimates for typical 1972–74 model year vehicles. Two evaporative emissions levels are shown: (i) the standard assumption the evaporative emission controls are 95 percent effective; and (ii) values estimated from the recent EPA surveillance study. Exhaust and evaporative HC emissions are added to give total HC emissions. Thus probable actual total HC emissions (5.1 g/mile) in these 1972–74 vehicles represent a 57 percent reduction from pre-1968 model year vehicle emissions (i.e. vehicles with no exhaust or evaporative emission controls, with exhaust HC at 8.7 g/mile and evaporative HC at 3 g/mile). Previous estimates had indicated that total HC emissions (assumed to be 3.2 g/mile) represented a 73 percent reduction. In Denver, the situation apparently is significantly worse since evaporative emissions in 1971 model year vehicles are three times as large as emissions measured at low altitude in Los Angeles with similar vehicles.

Of more significance, however, is the error in estimating the impact of the 1976 exhaust HC emission standard of 0.41 g/mile. Table 2 also shows estimates of 1976 model year vehicle total HC emissions based on the assumptions that the exhaust HC emission standard is met, but evaporative HC emissions remain at what appear to be current levels. Only a 51 percent reduction from 1972–74 model year total HC emissions would be achieved, as compared with the previous estimate which was an 81 percent reduction. Again the situation in Denver appears to be worse. Because only one of two apparently comparable HC emissions sources in current new vehicles will be required to satisfy strict emission standards in 1976, the net reduction in new car total HC emission levels will be much less than was originally intended.

Two immediate needs are obvious at this stage. First an accurate test procedure for measuring evaporative emissions must be developed which corresponds closely to "real life." It may well be that a careful evaluation will show that the SHED technique is adequate for this purpose. Second, an extensive study must be made to determine just what evaporative HC emissions from 1971, 1972, 1973 and 1974 model year vehicles are in actual use, in different parts of the country, under different ambient conditions.

TABLE 1.—MEASURED EVAPORATIVE HC EMISSIONS FROM VEHICLES WITH EVAPORATIVE CONTROLS

Model year	Number of vehicles	Evap. HC (gram/test)[1] Diurnal	Run + hot soak	Evap. HC[2] (gram/mile)
1970–71, Los Angeles	31	16.3	10.9	2.1
1971, Denver	20	47.2	34.8	6.4

[1] Data from ref. (5).
[2] (Evap. HC g/mile)=(diurnal g/test/27+(run. +hot soak g/test)/7.5.

TABLE 2.—1972–74 AND 1976 MODEL YEAR VEHICLE TOTAL HC EMISSIONS

[In grams per vehicle mile]

Model year	Exhaust HC emissions [1]	Previously assumed evap. HC emissions [2]	Probable actual evap. HC emissions [3]	Previously assumed total HC emissions [4]	Probable actual total HC emissions [4]
Nationwide (low altitude):					
(i) 1972–74	3	0.2	2.1	3.2	5.1
(ii) 1976	[5] .41	.2	2.1	.61	2.5
Denver (high altitude):					
(i) 1972–74	5	.2	6.4	5.2	11.4
(ii) 1976	[5] .41	.2	6.4	.61	6.8

[1] 1975 Federal test procedure CVS–CH.
[2] Value estimated from assumption that eveporetive HC standards are met in actuel use.
[3] Field surveillance deta (ref. 5).
[4] Exhaust HC+evaporetive HC; both emissions expressed in grams per vehicle mile.
[5] Assumes 1976 exhaust HC emissions standard met in actual use.

APPENDIX III: THE RELATIONSHIP BETWEEN FUEL ECONOMY AND EMISSION CONTROL FOR AUTOMOTIVE I.C. ENGINES

By John B. Heywod, Department of Mechanical Engineering, Massachusetts Institute of Technology, Cambridge, Mass.; Submitted to the Department of Transportation, Transportation Systems Center, Cambridge, Mass., Purchase Order TS–6059—August 2, 1973

SUMMARY

The factors which affect automobile fuel economy are reviewed, and the validity of the EPA CVS Emissions Driving Cycle as a fuel economy test is assessed. It is shown that the EPA Driving Cycle represents urban driving, but not urban-suburban or rural driving which are equally important in terms of gasoline consumption. The emission control potential and fuel economy of conventional spark ignition engines with catalysts and reactors, Wankel engines, stratified charge engines and diesel engines are then evaluated. Stratified charge engines are shown to offer the best emission control potential in actual use with a fuel economy gain relative to 1973 vehicles. The fuel economy penalty associated with the Federal Emission Standards for 1968–1973 model year vehicles is evaluated and shown to be about 13–18 percent for intermediate and standard size cars in urban and suburban driving. The fuel economy penalty for compact cars, however, is small.

1. Background

This report describes the fuel economy and emission control potential of different promising internal combustion engine concepts for automobiles. The concept examined are conventional carbureted spark-ignition engines with advanced emission controls and catalytic or thermal exhaust reactors, Wankel rotary combustion engines, stratified charge engines, of the Honda CVCC, Ford PROCO and Texaco TCCS type, and diesel engines. This report is based on data from the National Academy of Sciences Committee on Motor Vehicle Emissions study, from the Environmental Protection Agency and from the literature. It must be stressed, however, that the data on fuel economy and durability of advanced emission control systems from these sources is limited in extent.

The intent of this report is to assist the Department of Transportation in estimating the effects of changing internal combustion engine technology and emission regulations on automobile fuel economy. There is evidence that fuel economy has deteriorated as emission controls have been introduced in 1968–1973 model year vehicles. There is mounting pressure to improve the average fuel economy of the vehicle population. The 1976 NO_x emission standard may be adjusted in the light of revised air quality data. There is a strong interaction between the NO_x emission control required in an automobile and its fuel economy.

This report identifies engine and emission control concepts which promise low pollutant emissions over the vehicle lifetime with minimum performance penalties. The report contains the following sections. First the different methods frequently used to measure fuel economy are reviewed and their relevance to average driving patterns examined. Next, the methodology used to estimate the emission control achievable in actual use by different engine concepts is described. The performance of each of these systems is then examined in detail and the available fuel economy data tabulated and summarized. Data are also presented which show the effect of changes in the NO_x emission control level on fuel economy for some of these engine concepts. Finally, the effect of emission controls on the fuel economy of conventional engined 1968–1973 model year automobiles is examined.

2. Effects of Driving Pattern on Fuel Economy

Normal automobile driving is a sequence of many different modes: idle, acceleration, cruise, deceleration, etc. It is well known that both fuel economy and emissions vary with engine speed and load, and driving cycles have been developed to measure appropriately weighted average values of these parameters. Figure 1 shows how the road load cruise fuel economy of a 2,100 lb. sub-compact, a 3,500 lb. intermediate and a 5,200 lb. luxury sedan varies with speed. (1) Maximum fuel economy is obtained at about 40 mph. Figure 2 compares the 40 to 70 mph steady cruise fuel economy of these three vehicles with fuel economy measured over an urban driving cycle used by Chrysler. (1) The best fuel economy for each vehicle (40 mph cruise) is more than twice the worse (urban driving cycle with a cold engine).

Many different driving cycles are used to measure fuel economy. EPA has developed an urban driving cycle for emissions testing. (2) The cycle is based on vehicle speed traces over a Los Angeles traffic route known as LA–4. The route was developed by California agencies to simulate weekday morning peak driving conditions in a 12-mile diameter circle centered on the downtown area. Part of the LA–4 cycle was adopted as the driving cycle for the EPA CVS emissions test. The test is outlined in Appendix A. This EPA cycle consists of a 7.5 mile, 23 minute, nonrepetitive driving sequence. There are two versions of the emissions test. One, used for 1972–1974 model year vehicles, consists of a single cycle with a cold engine start-up (CVS-C). The other (CVS-CH) version of the test, used for post-1974 model year vehicles, has a cold start cycle followed by a 10 minute engine shutdown followed by a hot engine start and a repeat of the first 505 seconds of the 7.5 miles driving pattern. The cold start and hot start portions of the test are then weighted by 0.43 and 0.57 respectively. The emissions and fuel economy measured by these two tests are different. The CVS-C fuel economy (mpg.) is 2–5 percent worse than the CVS–CH fuel economy due to the higher weighting given the cold engine.

Is this driving cycle an adequate representation of urban driving? CAPE–10, (3) an APRAC project, conducted driving-habit studies in five major cities including Los Angeles. Driving pattern data from the LA–4 route, EPA CVS emissions cycle, the CAPE–10 Los Angeles and five city composite cycles are summarized in Table 1. A comparison of lines 1 and 3 shows that urban driving in Los Angeles (LA–4 cycle) has a significantly lower average speed, higher percent of time at idle and lower percent cruise time than average driving for the entire Los Angeles metropolitan area (CAPE–10 LA cycle). The EPA CVS cycle thus represents average urban type driving. It is less representative of driving in an entire metropolitan area (urban plus suburban).

There are other limitations of the CVS cycle as a fuel economy measurement. The driving is done on a dynamometer, not on the road. While the inertia of the vehicle is simulated during the cycle with appropriate inertia weights, the dynamometer power absorption unit is adjusted to reproduce road power at 50 mph cruise speed. (4) The tire pressure is usually increased to prevent tire damage. Thus aerodynamic drag and tire friction are not properly accounted for in the CVS fuel economy measurement. It has been suggested that differences between drivers over the CVS test produce differences in fuel economy, and that the use of a carbon dioxide measurement is less accurate than a measurement of weight of fuel consumed. However, these difficulties have not yet been adequately quantified.

The automobile manufacturers generally use urban-suburban driving cycles which have higher average speeds than the EPA-CVS cycle, and fewer stops. Thus standard size vehicles in 1965–67 model year (pre-emission control) with 350 CID engines had fuel economy as measured by manufacturers tests in the 15–17 mpg range, which is higher than the 12.5–14.5 average mpg measurements made by EPA (5) for 1965–67 3500–4000 lb. inerita weight vehicle range on the CVS cycle.

Total U.S. automobile gasoline consumption depends on nationwide mileage accumulation. Nationwide mileage accumulation is the sum of mileage accumulation on many different types of roads with different traffic patterns, e.g., urban, suburban, rural and interstate. Average speeds and types of driving in these categories are different, with average speed increasing, and number of steps per mile decreasing in the order listed. The effect of increased speed and fewer stops is illustrated by the data in Table 2. Two intermediate size cars were driven over two different types of routes. Though fuel economy in miles per gallon for both cars increases with average speed, the percentage increases are different (50 percent for the Plymouth, 30 percent for the Pontiac). Note also that the higher speed route, with ten stops in 27.7 miles, has fuel economy values considerably below cruise fuel economy at the average speed which would be about 23 mpg (see Figure 1) for these vehicles.

Fuel economy for different common types of driving will be affected differently by engine and transmission technology developments, by changes in body shape and vehicle weight, and by changes in tire design. Other factors of importance are the effect of ambient conditions, and the weighting given the cold engine portion of the driving cycle. There is a need, therefore, to understand how gasoline is consumed among these different common driving modes so that more accurate assessments of the effects of changing technology on total gasoline consumption can be made. While driving patterns in metropolitan areas are now adequately categorized, (3) it appears that rural and interstate driving patterns have not been quantified to the same extent.

3. Factors Controlling Emissions from Vehicles in Actual Use

The emission control systems described in the next section are not yet in mass production. The data available to evaluate their effectiveness come from experimental prototype vehicles. These are usually tested under conditions close to those used in the EPA 50,000 mile certification process. (4) Both the accelerated rate of mileage accumulation (50,000 miles in about 3 months) and the vehicle driving pattern in the EPA certification process make this testing less arduous than normal customer usage. The thermal cycling between normal engine shutdowns, sustained engine operation at high power levels, and normal abuse and neglect are all absent. Whether these differences between accelerated durability testing and actual use depends on the nature of the emission controls, and the importance of regular maintenance.

For the 1968–1973 model year vehicles, the certification process appears to have adequately evalnated the durability of emission controls. Emissions over 50,000 miles during certification have increased by between 0 and 40 percent. (6) (7) Emissions in actual use have on average increased by between 20 to 30 percent over the same mileage.

Current evidence shows, however, that with advanced emission control systems for 1975 and 1976 this will no longer be the case. (6) (7) The deterioration in actual use, especially of systems using catalysts, is expected to be more rapid. In some of the systems described in the next section, engine operating conditions must be very precisely controlled for emissions to approach 1976 levels. Slight changes in adjustments or operating conditions can significantly increase emissions. With systems using catalysts, the catalyst activity is expected to deteriorate more rapidly in actual use due to thermal cycling several times a day, a more demanding duty cycle—longer operating period at high temperature, and poorer control of catalyst poisons in the fuel.

In addition, average emissions from production vehicles are expected to be slightly higher than emissions from experimental prototypes. The reasons are that minor design changes are usually made to reduce costs and improve mass producibility, and that dimensional and operational tolerances are greater in the production vehicles. Most manufacturers estimate the increase in emissions for production vehicles to be about 10 percent.

The following methodology has therefore been used to estimate average emission levels from these different engines and emission control systems in actual use at 50,000 miles (about half way through the vehicle total accumulated mileage). The methodology is based on the EPA certification procedure for evaluating whether production prototypes comply with the applicable emission standards. (4)

Average emissions at 50,000 miles (grams per mile):
= Emissions at low mileage (grams per mile)
× 4,000 to 50,000 mile deterioration factor.
× prototype to production slippage factor.

The 4,000 to 50,000 mile deterioration factor is emissions at 50,000 miles/emissions at 4,000 miles (a number obtained from graphs of emission levels as a function of mileage). This number is evaluated from emissions data from vehicles with prototype engines which have accumulated mileage at an accelerated rate. It has been increased to allow for the anticipated more rapid deterioration in actual use.

Estimates of emissions in actual use are used in this report to evaluate the emission control potential of the different systems, because data from the accelerated durability testing to date presents an overly optimistic picture of the performance of systems incorporating catalysts.

It is assumed that the vehicle owner attempts to carry out the manufacturer's specified service and maintenance requirements. Under these conditions current engine emissions deteriorate in actual use by a factor of 1.2 to 1.3 over 50,000 miles. Certification deterioration factors from current production engines range from 1.0 to about 1.4. (7) The emissions in grams per mile relate to the 1975 CVS-CH EPA test procedure. The production slippage factor is always taken at 1.1.

A standard size care is taken to be a 4,500 lb. inertia weight vehicle with a 350 CID engine with an automatic transmission. A compact car is taken to be a Vega or Pinto size 2,750 lb. inertia weight vehicle with a 140 CID engine and an automatic transmission. VW, Honda, Toyota, Datsun and Mazda cars are slightly smaller than U.S. compacts.

It is stressed that these are estimates of emission control achievable in actual use, and not during the certification process. These estimates are an approximate indication of the real potential of each system. The emission levels achievable at low mileage, and the subsequent deterioration over 50,000 miles are engineering judgment made by the author from a limited data base.

The fuel economy figures given are actual data from the 1975 CVS-CH emissions test except where noted. These data have come from experimental prototypes and not production vehicles. They have not been adjusted. Where many manufacturers have similar prototypes (e.g., 1975 and 1976 systems with catalysts) the fuel economy for the 1975 CVS-CH emissions test has been estimated using average percentage reductions in fuel economy supplied by manufacturers, relative to 1973 model year vehicles, and average fuel economy data from Table 1 in the EPA Emissions-Fuel Economy Study. (5)

These fuel economy values represent performance to be expected in urban driving. In other types of driving fuel economy gains and losses may be different. For example, Chrysler estimates the loss in fuel economy due to emission controls between 1968–1973 model year vehicles to be 15% for urban driving but only 3% for 70 mph steady cruise. (1)

4. Fuel Economy Data and Potential Emission Control for Different Internal Combustion Engine Concepts

4.1 Conventional Engines with Engine Modifications, Catalysts and Thermal Reactors

Most production vehicles in 1975–1978 model years will use conventional engines. The lead times for developing acceptable alternatives and for production line conversion are too long for large scale introduction of new concepts to be practicable on a shorter time scale. Most manufacturers' efforts to develop systems to meet the 1975/76 standards have therefore concentrated on exhaust treatment devices to clean up the hydrocarbon (HC), carbon monoxide (CO) and oxides of nitrogen (NO_x) emissions from conventional spark-ignition engines. The engine emissions are usually controlled to a minimum consistent with acceptable fuel economy and performance penalties through improved carburetion (altitude compensation, quick acting choke, better metering accuracy), a quick heat manifold to promote more rapid fuel vaporization, an electronic ignition system, exhaust gas recycle for NO_x control, and modified spark timing. (6) (7) Catalysts (oxidation catalyst for HC and CO removal; reduction catalyst for

NO_x), and/or thermal reactors (for HC/CO removal) with the addition of secondary air into the exhaust ports, manifold or pipe are then used for the final emissions clean up. The most developed systems are the following:

(a) *1975 Prototype System with HC/CO Catalyst.*—Most manufacturers have been developing this system in their efforts to meet the 1975 HC and CO standards. The system typically consists of the engine modifications listed above with a palladium and/or platinum catalyst for HC and CO emission control in the exhaust. Emissions data are summarized in refs. (6) and (7). Table 3 shows estimated emission control achievable in actual use in a standard size car. It has been assumed that catalyst deterioration in actual use will be between 1.5 and 2 times the deterioration typical of accelerated mileage accumulation tests to date.

Fuel economy estimates by major manufacturers range from no change relative to 1973 vehicles(8) to about a 4 percent penalty.(9) These estimates are listed in Table 4. This system aims at NO_x emission levels of about 3 g/mile, the 1975 NO_x standard.

(*b*) *1975 Prototype System with HC/CO Catalyst and Increased EGR for Lower NO_x.*—NO_x emission can be reduced below the 1975 standard of 3.1 g/mile by increasing the percentage of exhaust gas recycle (EGR). An enrichment of the fuel-air mixture is required to partially offset the decreased flame speed which results from increased EGR. This enrichment minimizes the loss in driveability. The fuel economy deteriorates due to both the richer carburetor setting, and the decreased flame speed. A practical lower limit due to deteriorating vehicle driveability is reached at NO_x levels of about 1.5 g/mile with current production engines with engine modifications listed previously. Tables 3 and 4 give emission estimates and fuel economy(9) for this system.

Increasing EGR further does reduce NO_x emissions, but both fuel economy and driveability deteriorate. The effect on fuel economy of increasing EGR and mixture richness (both of these changes reduce NO_x emissions) can be estimated from Figure 3(10) which summarizes data from a number of sources.

(*c*) *1976 Prototype System with NO_x Catalyst and HC/CO Catalyst.*—The conventional spark-ignition engine requires a NO_x reduction catalyst to approach the 1976 NO_x standard of 0.4 g/mile. The total system most manufacturers have been developing consists of engine modifications as listed above, a NO_x catalyst (usually a noble metal) close to the exhaust manifold and a HC/CO catalyst further down the exhaust pipe. The carburetion is calibrated richer than in the 1975 system since the NO_x catalyst must operate in a net reducing atmosphere. During engine warm-up, the NO_x catalyst is used to control HC and CO emissions, and air is added to the exhaust gases in the exhaust ports. Once the engine and catalyst beds are warmed up, the secondary air is switched to downstream of the NO_x catalyst which then assumes its design role of NO_x reduction, and the second catalyst bed oxidizes HC and CO.

The durability of NO_x catalysts is currently inadequate. In addition, the complexity of this system and the need for precise control of air-fuel ratio make the production feasibility and in use maintainability of this system doubtful. In use estimates of emission control potential have not therefore been made. Most manufacturers estimate the fuel economy penalty of this system to be about 10 percent relative to equivalent weight 1973 model year vehicles.

(*d*) *Thermal Reactor System with Minimum NO_x.*—An exhaust manifold thermal reactor is an alternative to an oxidation catalyst. Lowest emissions result from systems with fuel rich carburetion where energy release from CO burn-up in the reactor holds the reactor at high temperature. Emission levels appoaching the 1975 standards can be achieved with reactor core temperatures of about 1,800° F, but the durability of the reactor under these conditions is inadequate.(7) Reasonable durability has been demonstrated at lower reactor temperatures and higher emission levels.(7) Table 3 gives estimates of levels achievable in actual use. Control of CO is more difficult than control of HC. The NO_x level primarily determines the fuel economy, and about a 10 percent penalty is estimated as indicated in Table 4.

A fuel-lean carbureted engine thermal reactor combination has been tested extensively by Ethyl Corporation.(7) One car at 50,000 miles has demonstrated emission levels of 1.1 g/mile HC, 7.9 g/mile CO, 1.6 g/mile NO_x. While all these emissions are above the 1976 standards, they are close to the 1975 California Interim standards. The attraction of this approach is that the fuel economy is comparable to 1973 conventional vehicle levels.

(e) *Questor Reactor NO_x Catalyst System.*—A reactor—NO_x catalyst system is being developed by Questor.(11) The engine is operated fuel rich. Partial air addition in the exhaust ports allows some CO and HC burnup in a manifold thermal reactor. The hot exhaust gases (still net reducing) then pass through a monel mesh NO_x catalyst bed. Secondary air is then added and the exhaust gases pass into a second thermal reactor for final HC or CO clean up. With a liquid quench system to prevent overheating of the NO_x catalyst, some durability potential has been demonstrated.(7) However, the complexity of the system and the failure potential of the catalyst quench concept raise serious doubts as to its mass producibility. Emission estimates have not been made.

The fuel economy is poor as shown in Table 4 due to very fuel rich carburetion. Fuel economy is improved at high speed cruise by leaning out the mixture (15.8 mpg at 60 mph steady state) but emission control is sacrificed.

4.2 Wankel Engine

The Wankel rotating combustion engine is in mass production by Toyo Kogyo, and is being developed for mass production in 1974 by General Motors. It is claimed that large scale mass production would bring significant cost reductions since the engine is smaller, lighter, has fewer parts (about two-thirds the number) and is better suited to fully automated assembly than an equivalent piston engine. However, the emissions and fuel economy characteristics of current production Wankel engines are not especially attractive.

The most durable emission control system is the thermal reactor. With a fuel-rich carburetor calibration, the engine has low NO_x emissions, and the reactor is especially effective for HC control which is the Wankel engine's worst emissions problem. Toyo Kogyo has demonstrated 1975 prototypes which meet 1975 certification requirements, but the potential for meeting the 1976 standards with the thermal reactor system for HC and CO control, and EGR for NO_x control, has not yet been demonstrated. Driveability problems limit the NO_x emissions in a compact car to about 0.8 g/mile.

Emission estimates and fuel economy data for Toyo Kogyo engines in Mazda vehicles are given in Tables 5 and 6. The 1973 Rotary Engine Mazda has a CVS fuel economy 29 percent worse than the average of its weight class piston engine 1973 vehicles (17.9 mpg, (5)). Fuel economy deteriorates as NO_x emissions are reduced to levels approaching the 1976 standard of 0.4 g/mile as indicated in line (d) of Table 6. The relatively poor fuel economy of this engine vehicle combination can be attributed to fuel-rich carburetion, to gas leakage past the engine apex seals, and the higher quench area and heat transfer surface of the Wankel engine relative to an equivalent piston engine. In addition, the engine power to vehicle weight ratio of the Mazda RX 3 is high relative to most conventional vehicles in the same weight class.

It has been estimated that a 50 percent reduction in seal leakage would reduce specific fuel consumption at 2,000 rpm by about 6.5 percent, and at 4,000 rpm by about 4.5 percent.(12)

4.3 Honda Compound Vortex Controlled Combustion (CVCC) Engine

This engine, recently developed by Honda into a low emission concept, uses a small prechamber around the spark plug, a dual carburetor dual intake system and two intake valves to control the combustion process. A fuel rich mixture is admitted to the prechamber via a small intake valve, and a fuel lean mixture to the main chamber via the normal intake valve. The burning jet issuing from the prechamber after spark plug discharge ensures good ignition of the very lean mixture in the main chamber. A slow burn is achieved by controlling the motion of the mixture in the main chamber. The slow burn reduces NO_x formation rates and allows HC and CO burnup to proceed late in the expansion stroke. Low engine emissions have been achieved without catalysts or EGR, though a manifold reactor is used.

The slow burn, divided combustion chamber and lean mixture reduced the maximum torque compared with a conventional engine for a given engine displacement. There is also a fuel economy penalty relative to an uncontrolled (pre-1968) conventional engine due to the slow burn of the engine and its higher surface area.

Emissions data have been taken on subcompact, compact and standard size vehicles.(13) Estimates of emission control and fuel economy potential for the Honda system are given in Table 7. Measured fuel economy data are given in Table 8.(13) It is stressed that the estimates in Table 7 are preliminary since the data base available for projections are limited. It appears that the 1975 Honda

CVCC system in a compact car (lines (a), (b), (c), and (e) in Table 8) has comparable fuel economy to equivalent 1973 vehicles (the 2 liter engine, 2,000 lb. inertia weight has a high power to weight ratio). The standard size car (line (f) in Table 8) has about a 10 percent improvement above its average 1973 equivalent. Modifications to reduce NO_x emissions (line (d) compared to line (b)) substantially deteriorate fuel economy.

4.4 Fuel Injected Stratified Charge Engines

Both Ford and Texaco have developed open chamber fuel injected stratified charge spark-ignition engines. While there are differences between these two engine concepts, both employ a combination of air inlet port swirl and high pressure time cylinder fuel injection to achieve a local fuel-rich mixture near the spark plug while the overall fuel-air ratio is fuel lean for most operating conditions. Additional controls are required to meet the 1976 standard emission levels. Current designs use noble metal HC/CO catalysts, and EGR for NO_x control.

Both Ford and Texaco have developed and tested 4 cylinder 70 HP engines for the N.S. Army Tank-Automotive Command military jeep. These have been tested over extended mileage. The emission levels and fuel economy of the two concepts are comparable. Ford has developed 4 and 8 cylinder versions of its stratified charge engines for passenger cars, and low mileage emissions and CVS fuel economy data are given in Table 9. The available data are currently inadequate to estimate emissions in actual use over extended mileage. However, the HC level of 1 g/mile projected for a conventional engine with HC/CO catalyst in line (b) in Table 3 should be achievable, and CO levels should be significantly below the conventional engine 10 g/mile estimate. NO_x emissions of 0.5–0.6 g/mile might be attained. Note that the fuel economy of this system shows a considerable improvement (in the 10–40 percent range) over equivalent weight conventional 1973 vehicles.

This system is still in the development stage, and major problems with mass production of the fuel injection system, and spark-plug and ignition system have yet to be resolved.

As with other internal combustion engine systems, the fuel economy depends on the level of NO_x emission control achieved. For example, the original Texaco L–141 70 HP 4 cylinder engine in the military jeep when optimized for maximum economy showed a 30 percent fuel economy advantage over the conventional carbureted L–141 jeep engine. With increasing EGR and intake throttling, the fuel economy deteriorates. With the Texaco jeep engine with NO_x emissions at 0.3–0.4 g/mile, fuel economy comparable with the original carbureted engine is achieved. With NO_x at 0.7 g/mile, about a 10 percent fuel economy gain relative to the conventional engine is obtained. Figure 3 shows the fuel economy-NO_x emissions curve for two vehicles equipped with the TCCS stratified charge engine.

4.5 Diesel Engines

A number of diesel engine passenger cars are available in the United States and Europe. Emissions data in Table 10 show these vehicles have the potential for meeting the 1975 standard with NO_x emission levels in the 1–2 g/mile range. All these engines are 4 stroke divided chamber engines, and the Opel and Peugeot use the Ricardo Comit cylinder head design. Daimler-Benz estimates that the lowest NO_x level achievable for diesels at the present state of the art would be about 0.8 g/mile. (6) Fuel economy would deteriorate as NO_x emissions are reduced.

A passenger car diesel engine designed according to existing technology would have higher initial cost, greater weight and larger size than a conventional spark-ignition engine of comparable output. It would give better fuel economy. The fuel economy values in Table 10 are for vehicles with a low power to weight ratio, however, as indicated by the 0–60 mph acceleration times which are at least twice as long as those of conventional spark-ignition engined vehicles.

A diesel engine technology more suited to automobile use could be developed with reduced engine weight and size. However, the additional problems of smoke, odor and noise would have to be resolved before the diesel power plant would be an attractive alternative. The development of stratified charge engines would bring performance improvements comparable to those an advanced diesel engine technology would offer. This appears to the author to be a more likely development from current conventional engine technology.

4.6 Summary

Table 11 summarizes the emission estimates and CVS fuel economy relative to equivalent weight 1973 vehicles. The attractions of the stratified charge engine concepts are clear. The emission estimates can be compared with the emission standards for 1975 and 1976 in Table 12.

5. Fuel Economimy Penalty Associated With Emission Control 1968–73

There is considerable debate as to the magnitude of the fuel economy penalty associated with the introduction of emission controls of increasing strictness in 1968–1973 model years. Estimates of the magnitude range from about 7 percent (5) to more than 20 percent. Fuel economy data for two different model vehicles over this time period are given in Table 13. Both cars have experienced a 20 percent fuel economy penalty, but both have experienced an increase in weight.

The weight increase for the Ford vehicle is 20 percent. Chrysler data (1) on a standard size car indicates an increase in fuel consumption of 0.5 mpg for a 10 percent increase in vehicle weight for urban driving. Thus about two thirds of the total fuel economy penalty in Table 13 can be attributed to emissions control for this urban-suburban type of driving cycle.

EPA data (5) shows similar trends for standard size cars. Table 14 gives average pre-1968 vehicle CVS fuel economy, and average 1973 vehicle fuel economy, for different vehicle inertia weights. Subcompact and compact cars show little fuel economy loss. Intermediate and standard size cars show a significant fuel economy loss.

One reason for the different trend in compact sized vehicles is that the emission reduction required to meet the standards is less for CO and NO_x in compact cars than in large cars. Emissions data from 1963–67 precontrol model year vehicles indicate that CO and NO_x emissions for cars tested at less than 3,000 lb. inertia weight were 25 percent lower than emissions from cars tested at more than 4,000 lb. inertia weight. HC emissions for these two weight categories were not significantly different, however. (14)

Another reason is that compact pre-emission control vehicles were carbureted significantly richer than intermediate and standard size pre-emission control vehicles (the $CO:CO_2$ ratio is substantially higher in the emissions data in ref. (14)). To meet emission standards all manufacturers have leaned out carburetor calibrations, and the spread in carburetor calibrations between different weight vehicles has been much reduced. A third reason compact cars show little fuel economy penalty is that as emission standards have become more strict, the technology used for fuel metering has had to be improved. For example, many manufacturers have introduced electronic fuel injection.

One consequence of such changes has been an improvement in fuel economy in compact cars due to fuel system changes. This improvement has offset the losses which would have resulted from engine modifications (such as reduced compression ratio, modified spark timing and exhaust gas recycle) introduced to meet emission standards. In intermediate and standard size cars, fuel metering technology was already superior and no substantial gains were realizable through changes in technology. The decrease in fuel economy in miles per gallon in a given vehicle weight class is directly attributable to emission controls.

That the fuel penalty for vehicles with inertia weights greater than 4,000 lb. from the EPA data (17–18 percent) is larger than the change in fuel economy due to emissions (about 13 percent) in Table 13 data is not necessarily inconsistent since the driving cycles are not the same.

A large part of this fuel economy penalty is due to the reduction in compression ratio in 1971 or 1972 model year to allow engines to be run on 91 research octane number gasoline. Roensch (15) estimates this fuel economy loss as 5.2 percent for regular fueled and premium fueled vehicles, respectively, with no increase in engine size to offset the performance loss. The fuel economy penalties would be 7.8 and 13.3 percent if engine performance is held constant.

Since intermediate and standard size cars are the majority of the car population, and consume substantially more gasoline per mile than compacts, their fuel economy loss will dominate the national average loss due to emission control.

6. Conclusions

1. There is a need to understand in greater detail how the nation's gasoline production is consumed. Important factors to determine are miles traveled, typical driving patterns and average fuel economy for different types of automobiles on different types of roads. This information is required at different levels and on different time scales. The short term need is to assess approximately, the

valididy of currently used fuel economy tests as measures of nationwide fuel consumption. The medium term need is to develop a more appropriate fuel economy measurement procedure which is representative of average nationwide driving patterns and mileage accumulation. The long term need is for a more accurate data base with which to make projections of the effects of changes in vehicle technology and vehicle use patterns on total U.S. gasoline consumption.

2. Stratified charge engines, both spark-ignition and diesel offer improved fuel economy and reduced emissions due to inherent design features when compared with conventional spark-ignition engines. Conventional engines require a variety of add on devices to meet various pollution standards, whereas stratified charge engines can achieve significantly lower engine emissions without such add ons. The emission levels required, and especially the NO_x level, strongly influence the choice of most promising engine type and the fuel economy which can be achieved.

3. Manufacturers' efforts to meet Federal Emission standards (1968–73) have resulted in a fuel economy penalty in miles per gallon of about 13 to 18 percent for urban driving for the larger intermediate and for standard size cars. Compact cars have suffered little fuel economy penalty, because emission levels for CO and NO_x in pre-emission control compact vehicles were lower than in larger cars, and because improvements in fuel metering technology have offset losses due to emission controls.

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TABLE 1.—BREAKDOWN BY MODE OF URBAN DRIVING CYCLES

Cycle	Average speed (miles per hour)	Percent time in each mode			
		Idle	Cruise	Acceleration	Deceleration
LA-4	20.9	13.6	27.3	31.7	27.5
EPA-CVS	19.7	18.2	30.2	27.7	23.9
CAPE-10 LA	29.3	10.1	34.3	29.4	25.8
CAPE-10 composite	26.0	13.0	31.6	29.1	26.3

TABLE 2.—EFFECT OF AVERAGE SPEEO ANO NUMBER OF STOPS ON FUEL ECONOMY [1]

	City route	City and expressway
Length (miles)	18.4	27.7
Average speed (miles per hour)	23	36
Stops per mile	2.17	.36
Fuel economy (miles per gellon):		
1971 Plymouth Fury III, 360 CID engine	11.1	16.7
1970 Pontiac LeMans, 400 CIO engine	11.5	14.9

[1] Source: Ethyl Corp.

TABLE 3.—ESTIMATED EMISSIONS OF CONVENTIONAL ENGINE 1975-76 SYSTEMS [1]

System	Prototype low mileege emissions (gallons per mile) [2]			Estimated 50,000-mile deterioration factor in ectuel use			Estimated 50,000-mile emissions in use, (gallons per mile) [4]		
	HC	CO	NO_x	HC	CO	NO_x	HC	CO	NO_x
(a) 1975 system HC/CO catalyst	0.3	3.5	2.2	2.5	2.0	1.2	0.8	8	3.0
(b) 1975 system HC/CO catalyst increased EGR	.35	4.5	...	2.5	2.0	..2	..0	10	1.5
(c) 1976 system HC/CO catalyst NO_x Catalyst [3]	.2-.5	1-4	.2-.5						
(d) Thermal reactor system with minimum NO_x	.6	11	1.1	1.2	1.2	1.2	.8	15	1.5
(e) Questor system [3]	.2	2.3	.38						

[1] Standerd size 4,500 lb inertia weight vehicle; 350 CID engine.
[2] 1975 EPA CVS-CH test procedure.
[3] Inadequate deta to estimate emissions in actuel use. Systems complex and mass production feesibility marginal.
[4] Production slippege fector is 1.1.

TABLE 4.—CVS FUEL ECONOMY, CONVENTIONAL ENGINE SYSTEMS

System [1]	CVS fuel economy miles per gallon	Percent penalty relative to 1973 (percent) [3]
(a) 1975 system HC/CO catalyst	10.1-9.7	0-4
(b) 1975 system HC/CO catalyst increesed EGR	9.2	9
(c) 1976 system HC/CO catalyst NO_x catalyst	9	~10
(d) Thermel reector system with minimum NO_x	9	~10
(e) Questor system [2]	6.9-8.0	~20

[1] Stenderd size 4,500-lb. inertia weight vehicle; 350 CIO engine.
[2] Average 1973 fuel economy: 4,500 lb. 10.1 mi/gal; 5,000 lb. 9.4 mi/gel (urben-suburben driving).
[3] 5,000-lb. inertia weight vehicle; 400 CIO engine.

TABLE 5.—ESTIMATED EMISSIONS FDR WANKEL ENGINE IN COMPACT CAR [1]

System	Estimeted low mileege emissions (gelions per mile)	50,000-mile deterioration fector in actual use	Estimated 50,000-mile emissions [3] (gallons per mile)
Wankel engine thermel reactor EGR:			
HC	0.4	1.2	0.6
CO	3.0	1.2	4.0
NO_x	.5	1.2	.7

[1] 2,750-lb. inertia weight vehicle.
[3] Production slippege factor of 1.1 essumed.

TABLE 6.—FUEL ECONOMY OF ROTARY ENGINE MAZDA

System [1]	CVS fuel economy (miles per gallon)	Percent penalty relative to 1973 Wankel
(a) 1973 Mazda RX-3, 4-speed manual transmission, thermal reactor	12.7	
(b) 1975 Mazda RX-3, thermal reactor, richer carburetion, manual transmission	12.4	2
(c) Same with automatic transmission, 1976 Mazda RX-3	11.9	
(d) Thermal reactor, richer carburetion, EGR for minimum NO_x, manual transmission	11.2	12

[1] 2,750 lb. inertia weight 35 CID × 2 rotor engine.

TABLE 7.—ESTIMATES OF EMISSIONS POTENTIAL FOR HONDA CVCC ENGINE

	Estimated low mileage emissions (gallons per mile) [1]	Estimated 50,000-mile deterioration	Estimated 50,000-mile emissions in use [2] (gallons per mile)	Estimated CVS fuel economy (miles per gallon)
Compact 2,750-lb. vehicle, Honda 140 CID CVCC engine, automatic transmission:				
HC	0.3	1.2	0.4	
CO	3	1.2	4	~18
NO_x	.9	1.2	1.2	
Standard 4,500-lb. vehicle, Honda 350 CID CVCC engine, automatic transmission:				
HC	.4	1.2	.5	
CO	4	1.2	5	~11
NO_x	1.2	1.2	1.6	

[1] Data from reference (13) are adjusted for estimated minimum NO_x emissions consistent with acceptable fuel economy.
[2] Production slippage factor of 1.1 assumed.

TABLE 8.—FUEL ECONOMY DATA FOR VEHICLES TESTED WITH HONDA CVCC ENGINE

Vehicle	Engine size	Inertia weight, pounds	NO_x emissions, grams per mile	CVS fuel economy, miles per gallon	Average 1973 CVS fuel economy, same weight, miles per gallon
(a) Honda Civic, manual transmission	1.6 liter	2,000	0.93	25.4	25.5
(b) Honda Civic, manual transmission	2 liter	2,000	.95	22.0	25.5
(c) Honda Civic, automatic transmission	do	2,000	1.2	21.0	25.5
(d) Honda Civic, manual transmission with EGR	do	2,000	.24	18.1	25.5
(e) GM Vega, CVCC engine, manual transmission.	140 CID	2,500	1.2	18.6	19.9
(f) GM Impala	350 CID	4,500	1.2	11.0	10.1

TABLE 9.—LOW-MILEAGE EMISSION LEVELS AND CVS FUEL ECONOMY FOR FORD PROCO ENGINE VEHICLES

[All vehicles use EGR and noble metal catalysts]

	CVS/CH test (grams per mile)			CVS fuel economy (miles per gallon)	Inertia test weight (pounds)	Average CVS fuel economy of 1973 vehicles of same weight (miles per gallon)
	HC	CO	NO_x			
PROCO 141-CID Capris	0.12	0.46	0.32	20.4	2,500	19.9
Do	.13	.18	.33	25.1	2,500	19.9
Do	.11	.27	.32	22.3	2,500	19.9
PROCO 351-CID Torino	.30	.37	.37	14.4	4,500	10.1
PROCO 351-CID Montegos	.36	.13	.63		4,500	10.1
Do	.33	1.08	.39	12.8	4,500	10.1

TABLE 10.—PASSENGER CAR OIESEL ENGINE[1]

Make	Vehicla Inertia weight (pounds)	Emissions (gellons per mila)[2] HC	CO	NO$_x$	Fuel economy (milas per gallon)	Acceleration time 0 to 60 mi/h[3] (seconds)
Mercedes 2200	3,500	0.28	1.1	1.5	23.6	40
Opel	3,000	.4	1.2	1.3	23.2	28
Peugeot	3,000	3.1	3.4	1.1	24.2	24

[1] Oata presented by EPA et contractors meeting, June 7, 1973.
[2] Maesurad by EPA.
[3] 0 to 60 mi/h acceleration time for convantional automobile is 10 to 15 seconds.

TABLE 11.—SUMMARY OF EMISSION ESTIMATES ANO FUEL ECONOMY PENALTY FOR DIFFERENT SPARK IGNITION ENGINE CONCEPTS

System	Car size	Emissions[1] g/mile HC	CO	NO$_x$	Fuel economy percent change 1973[2]
1. 1975 system conventional engine; engine modifications HC/CO catelyst EGR.	Standard	0.8	8	3.0	−2
2. Same as 1 with increased EGR	do	1.0	10	1.5	−9
3. Conventional angine; engine modifications thermal reactor meximum EGR.	do	.8	15	1.5	−9
4. Wenkel engine; thermal reactor EGR	Compact	.6	4	.7	−(25–40)
5. Honda CVCC	do	.4	4	1.2	0
	Standard	.5	5	1.6	+10
6. Ford PROCO;[3] HC/CO catalyst EGR	do	~1.0	~4	~6	+25

[1] Estimates of emissions at 50,000 miles in actual use.
[2] Fuel economy penalty (−) or gein (+) relative to average mpg fuel economy of aquivelent inertia weight 1973 vehicla measured on EPA CVS emission test driving cycle.
[3] Estimates based on very limited data. Approximate magnitude only.

TABLE 12.—EMISSION STANOAROS FOR 1973, 1975, AND 1976 MOOEL YEAR VEHICLES

Year	Emission standard, g/mile HC	CO	NO$_x$
1973[1]	3.00	28.0	3.1
1975 interim:			
California	.90	9.0	2.0
Rest of Nation	1.50	15.0	3.1
1976	.41	3.4	.4

[1] Expressad in terms of 1975 CVS–CH test procedure.

TABLE 13.—OETERIORATION IN FUEL ECONOMY WITH MOOEL YEAR OF 2 STANOARO SEOANS

Model year	Ford standard size[1] sedan: Weight,[2] pound	Fuel economy,[3] miles per gallon	Oldsmobile standard size[4] seden, fuel economy,[5] miles per gallon
1965	3,550	15.0	
1966			17.0
1968	3,750	14.5	16.7
1970			16.0
1971	4,150	13.0	14.3
1972			14.6
1973	4,275	12.0	13.6

[1] Small V–8 engine, automatic transmission, power steering and brakes. Reference 9.
[2] The inertia weight for the EPA CVS emissions test is the vehicle curb weight given here plus 300 lb.
[3] Urben-suburban driving.
[4] 350 CID engine, automatic transmission, power steering, and brakes. Source: NAS CMVE Oata.
[5] Urban-suburban driving; not comparable to (3).

TABLE 14.—COMPARISON OF CVS FUEL ECONOMY PRE-1968 AND 1973 VEHICLES

Vehicle inertia weight	CVS fuel economy, miles per gallon		
	Average pre-1968	Average 1973	Percent penalty
2,000 pounds	25.7	25.5	1
2,750 pounds	17.9	17.9	0
3,000 pounds	16.3	16.2	0
3,500 pounds	14.4	14.0	3
4,000 pounds	13.5	11.2	17
4,500 pounds	12.2	10.1	17
5,000 pounds	11.4	9.4	18

Source of data: Reference (5).

APPENDIX A

FEDERAL EMISSION TESTING PROCEDURES FOR LIGHT DUTY VEHICLES

The Federal procedures for emission testing of light duty vehicles involves operating the vehicle on a chassis dynamometer to simulate a 7.5 mile (19722 procedure) or 11.1 miles (1975 procedure) drive through an urban area. The cycle is primarily made up of stop and go driving and includes some operation at speeds up to 57 mph. The average vehicle speed is approximately 20 mph. Both the 1972 and 1975 procedures capture the emissions generated during a "cold start" (12-hour soak at 68°F to 86°F before start-up). The 1975 procedure also includes a "hot start" after a ten minute shut-down following the first 7.5 miles of driving.

Vehicle exhaust is drawn through a constant volume sampler (CVS) during the test. The CVS dilutes the vehicle's exhaust to a known constant volume with make up air. A continuous sample of the diluted exhaust is pumped into sample bags during the test.

Analysis of the diluted exhaust collected in the sample bags is used to determine the mass of vehicle emissions per mile of operation (grams per mile). A flams ionization detector (FID) is used to measure unburned hydrocarbon (HC) concentrations. Non-dispersive infrared (NDIR) analyzers are used to measure carbon monoxide (CO) and carbon dioxide (CO_2). A chemiluminescence (CL) analyzer is used to determine oxides of nitrogen (NO_x) levels.

These procedures are used for all motor vehicles designed primarily for transportation of property and rated at 6,000 pounds GVW or less, or designed primarily for transportation of persons and having a capacity of twelve persons or less. Each new light duty vehicle sold in the United States in model years 1973 and 1974 must emit no more than 3.4 gpm HC, 39. gpm CO and 3.0 gpm NO_x when using the 1972 procedure. In 1975 the standards will change to .41 gpm HC 3.4 gpm CO and 3.1 gpm NO_x using the 1975 procedure. In 1976 the standards will be .41 gpm HC, 3.4 gpm CO and .4 gpm NO_x using the 1975 procedure.

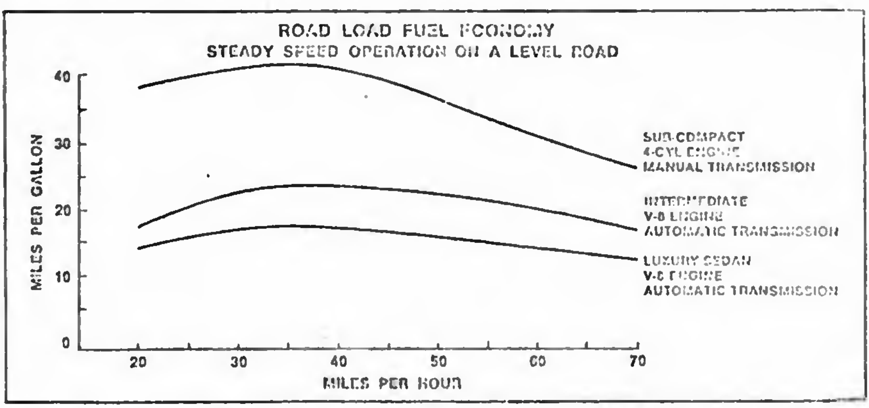

FIGURE 1.—*Road load fuel economy as a function of vehicle speed for three cars. Compact: 2,100 lb. 4 cylinder engine, manual transmission vehicle. Intermediate: 3,500 lb. V–8 engine, automatic transmission vehicle. Sedan: 5,200 lb. large V–8 engine, automatic transmission vehicle. Reference (1).*

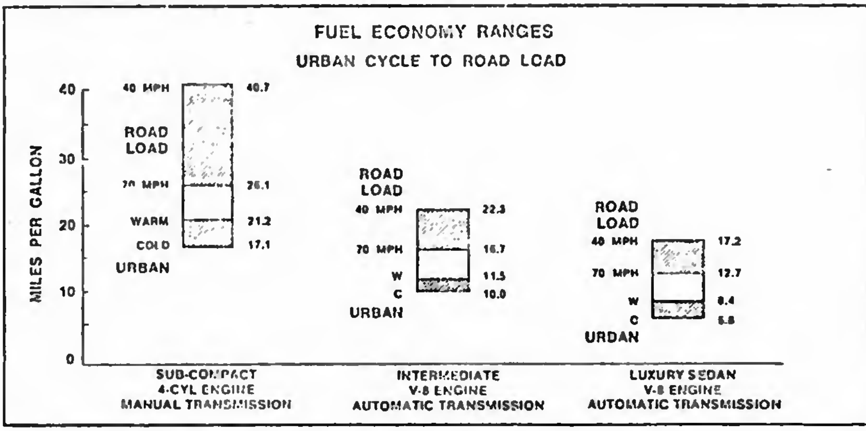

FIGURE 2.—*Fuel economy for cold and warm urban cycles, and 40 and 70 mph steady speed cruise for three types of vehicle. Urban cycle has 16% time at idle, 31% acceleration, 18% deceleration, 35% road load (similar to EPA CVS Driving Cycle).*

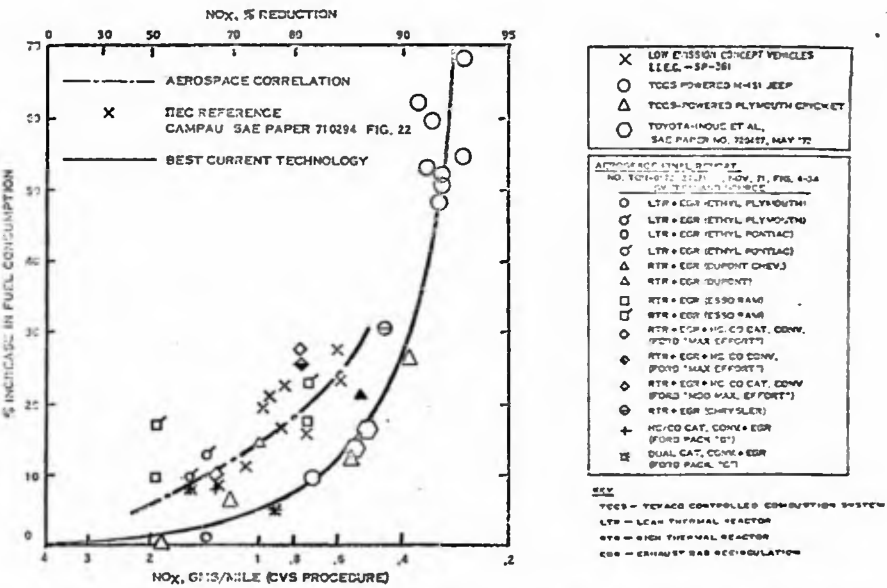

FIGURE 3.—*Effect of NO_x level in vehicle exhaust on fuel consumption. Data shown are from conventional engine vehicles with EGR and mixture enrichment to reduce NO_x emissions, and from Texaco TCCS stratified charge engine vehicles. Fuel consumption (gal/mile) is as measured on CVS cycle. Reference (10).*

Mr. ROGERS. Thank you very much, Dr. Heywood.

This is very helpful to the committee, because we must make some judgments on what we have heard today as to what action should be taken. Your study is right in line.

Mr. Symington?

Mr. SYMINGTON. Thank you very much, Mr. Chairman.

Professor Heywood, you heard the testimony immediately preceding your own, I think?

Mr. HEYWOOD. Yes.

Mr. SYMINGTON. And they seemed to spend some time, Dr. Balgord, in describing changes in spark.

Does that seem to be the same direction of your experience or would you be able to tell from what they said?

Mr. HEYWOOD. I have not had an opportunity to read their detailed testimony, Mr. Symington.

Mr. SYMINGTON. It might be that you can compare notes. I hate to think of great minds not thinking alike if they can.

I notice in your conclusions, later on in appendix III, page 21, you do make the point that we have to learn how the Nation's gasoline production is consumed. The question I earlier was about to ask and did not get to had to do with the car miles that are likely to be driven at a time when the decisions we make today become operative, and I think you are addressing yourself partly to that in stating this criteria.

Mr. HEYWOOD. Well, in the study I did for the Department of Transportation, I tried to summarize that we needed to know about how we use gasoline and make some statements about what I feel we did not know. And I feel we do not know the driving patterns that are typical of rural and suburban areas nearly as well as those that are typical of urban areas, and these are important factors that we should understand better before we attempt to regulate in the fuel economy area.

Mr. SYMINGTON. I think that is right, and we might also be trying to project the number of cars that will be on the road, based on the other kind of decisions that are being made. That might be more difficult.

Mr. Chairman, I would like to ask another question of the witness.

We were told some months ago that the Japanese had developed a system for cutting off the ignition during a long idle, with the trade-off reasonably precise, so that there would be a fuel benefit and not a loss.

Are you familiar with that?

Mr. HEYWOOD. I have heard about it; yes.

Mr. SYMINGTON. And that the depression of the accelerator after the ignition has, or rather after the idle has ceased, reignites and the car starts up. And I wondered if, in your studies, especially relating urban to rural, whether you factored in the amount of time spent idling as distinct from actually driving, and the possible usefulness of such a device.

Mr. HEYWOOD. No; that was not done, and I do not believe that type of study has been done yet. I feel it needs to be done.

Mr. SYMINGTON. I wonder if you could see what you could learn about it and let the committee know, perhaps at a later date, by letter or memorandum, if you think there is any hope in that area.

Mr. HEYWOOD. I will try to do that; yes.

Mr. SYMINGTON. Thank you.

Mr. ROGERS. Thank you.

Dr. Carter?

Mr. CARTER. Thank you, Mr. Chairman.

I certainly think you have a very scholarly presentation here today. I notice that you mention only one engine which has a possibility of reaching NO_x standard; is that correct?

Mr. HEYWOOD. Yes. My own feeling is that the dual catalyst system, which we investigated quite thoroughly in the National Academy of Sciences study, is too complicated to be able to achieve the original 1976 emission levels in actual use.

Mr. CARTER. Do you think that there is some hope that by use of the fuel injected stratified charge engine we might reach the NO_x standards?

Mr. HEYWOOD. I think there is some hope but I would repeat the remarks that I made earlier, that there is no strong evidence to date that that 0.4 grams per mile NO_x level is in fact required.

Mr. CARTER. Do you think that this committee has gone too far too fast?

Mr. HEYWOOD. Yes; and that is the thrust of my statement. I believe the clean air amendments were too strict too fast. If you look at the graphs that I present in appendix I, you will see that I have shown average urban emission rates for hydrocarbons and CO, and projected these into the future. You will see that the original intention of the clean air amendments is the solid line at the bottom of those curves, that is, for hydrocarobns the 0.41 grams per mile line on figure 1. It is very close to the dash line, about a quarter of an inch above it, which shows what happens if we have the interim standards for 5 years, and then in 1980 bring in the original 0.41 gram per mile standard.

The reason that the difference is not more is the following: It is the difference between the dirty car which one pushes out of the car population and the clean car that one replaces it by that matters.

If one looks in 1976, for example, average emissions are 30 grams per mile for CO. A dirty car that is scrapped out of the population has, typically, emissions of 80 grams per mile. If one puts in a new car with 15 grams per mile, or with 3.4 grams per mile emissions, both are sufficiently below 80, that the reduction in emissions is almost identical.

Mr. CARTER. Do you feel as if we should relax the standards, as the administration has advised for 2 years?

Mr. HEYWOOD. I believe that the change in air quality from continuing the 1975 interim standards for hydrocarbons and CO for 3 years, and then following those standards by the stricter standards that were originally mandated, is very little different compared to change with the original schedule. These calculations that I have presented, I feel, show this.

Mr. CARTER. Do you think that is the direction in which we should proceed or not?

Mr. HEYWOOD. I believe that is the direction you should proceed in; yes.

Mr. CARTER. Thank you, sir.

Mr. ROGERS. Mr. Heinz?

Mr. HEINZ. Thank you, Mr. Chairman.

And I thank you very much, Professor Heywood, for some excellent testimony.

Let me ask you, Did I hear you correctly that you were not familiar with the Balgord research?

Mr. HEYWOOD. That is correct. I am not familiar with it.

Mr. HEINZ. Very well.

I was interested in your testimony on page 2, where you indicated that some comparison between emission rates at 1980—and you made the comparison of the 76-percent achievement with one level of control, which is 64-percent level of control. And what you were saying in effect was that the new technology we are mandating might not have a very high cost-benefit ratio. I guess is what, another way of stating what you have stated to us.

How do you feel about retrofitting as a means of cleaning up the air? Should we deem that desirable, in your judgment would that have a greater cost benefit?

Mr. HEYWOOD. Well, I have studied retrofit in the Columbia, Harvard, MIT program I mentioned, and one conclusion is retrofits are very difficult to install. One can design a retrofit program for the in-use vehicle population that does give a significant gain in hydrocarbon and CO emissions if one could implement it right now. But one must be realistic about the time scales of implementing retrofit. First, more extensive tests on retrofit devices are required, because they have not been tested in sufficiently large numbers to date for one to be certain there would be no adverse effects on the vehicles they were installed on. Second, inspection programs need to be implemented, because it has been shown that retrofit is not effective without the backup of an emissions inspection.

Then one has to manufacture these devices, and then the service industry has to install them on something like 30 million vehicles if one considers the areas of the country where air quality is in need of substantial improvement. That would require I estimate an expansion of the service industry of 20 percent, to carry out this retrofit in 1 year; 10-percent expansion would do it in 2½ years.

My judgment is, it is unlikely the service industry is going to expand very much at all. Therefore, the date by which one could complete a retrofit turns out to be the late 1970's. By that time, the new car emission controls have significantly reduced average emissions, and the value of the retrofit is marginal.

Mr. HEINZ. Because your population has turned over so much by then?

Mr. HEYWOOD. That is right.

Mr. HEINZ. That is very interesting.

On page 4 you indicate with reference to the system that you were describing, that a system can be developed within 3 years to achieve the 1975 interim standards, or even the California 1974 interim standard.

When you say 3 years, what do you mean?

Do you mean that it can be developed and introduced in the model year, that is 3 years from today?

Or do you mean that it would be ready for introduction on the next model year after 3 years from today?

Mr. HEYWOOD. I mean it should be in large scale mass production in 3 years.

Mr. HEINZ. In 3 years from now.

Mr. HEYWOOD. Yes. But I would like to add a comment here. When we look at technological feasibility, we tend to equate the phrase with demonstration of mass production in units of about 300,000 or so a year. There is an additional phase required with much new technology. That is the conversion of old facilities to produce the new technology.

For new engines this is particularly important, because while one may be able to bring out one new engine in a 3-year period, and for example, Ford and Chrysler have suggested they could do this with the Honda concept, to convert all of their production facilities to this new concept would take very substantially longer than this 3-year period. And that second phase is often left out of considerations of going all the way across the board with the new technology.

Mr. HEINZ. I thank you very much.

Mr. ROGERS. As I understand it, then, you are saying you think it is all right to use Federal interim standards for 1975 or California interim, but not to freeze 1974 standards.

You would oppose freezing the 1974 standards?

Mr. HEYWOOD. I would oppose freezing the 1974 standards for several years. For 1 extra year it does not make a great deal of difference. For 2 years it makes more difference. By the time you have got to 3 years, it starts to make a substantial difference to the rate of reduction of average emissions, and the graphs that I attach in appendix I show this.

Mr. ROGERS. Yes; thank you.

Now, one final question. We are going to give you the testimony of Dr. Balgord. Now, if you can see that that can be done with present technology, would this change your testimony at all?

Mr. HEYWOOD. If I saw that it could be done with present technology in large scale mass production in actual use.

Mr. ROGERS. I would assume that would have to be the criteria for any judgment you have made, along with knowing that it could meet these standards, which incidentally, they tested and showed that they can even meet the NO_x standards for 1976.

Now if this is so and it has legitimacy, then you would change your viewpoint, I presume?

Mr. HEYWOOD. If that was so, I would legitimately believe it. But let me make the point that there are many test vehicles now in existence which meet the original 1976 standards.

Mr. ROGERS. Yes.

Mr. HEYWOOD. But that does not necessarily show that large scale mass production of vehicles which will meet the standards in actual use is feasible.

Mr. ROGERS. Well, nor does it show that any attempt to mass produce them has been made, does it?

Mr. HEYWOOD. That is correct.

Mr. ROGERS. Which may be the more important point.

If it can be done, I would think the genius of America could do it; would you not?

Mr. HEYWOOD. Yes.

Mr. ROGERS. If we may, we may call on you as we get further into this problem, to have you give us some of your advice, as you are most knowledgeable and have studied this. We are very grateful to you for being here and particularly for taking so much of your time to let us have the benefit of your thoughts and to be patient enough with us to stay this long.

Mr. HEYWOOD. You are welcome.

Mr. CARTER. Mr. Chairman, one comment if I might.

Mr. ROGERS. Yes.

Mr. CARTER. You spoke of American ingenuity. Are you an American by birth?

Mr. HEYWOOD. No; I am British by birth.

Mr. CARTER. I thought you were.

Mr. ROGERS. Are you an American citizen?

Mr. HEYWOOD. No, I am not yet, sir.

Mr. ROGERS. Not yet, but you plan to be?

Mr. HEYWOOD. I probably plan to be.

Mr. ROGERS. Yes; American ingenuity.

Thank you for being here.

Our last witnesses in the panel, and they tell me they are going to make it very short—Mr. Robert S. Leventhal, executive vice president of Engelhard Industries, Murray Hill, N.J., and Mr. Jim Dunham, director of the Automotive Product Division, Universal Oil Products.

We welcome you gentlemen. Your statements will be made a part of the record, and if you could highlight for us the vital statistics you think are necessary.

STATEMENTS OF ROBERT S. LEVENTHAL, VICE PRESIDENT, ENGELHARD MINERALS & CHEMICALS CORP., AND EXECUTIVE VICE PRESIDENT, ENGELHARD INDUSTRIES DIVISION; ACCOMPANIED BY JOHN J. MOONEY, MANAGER, AUTOMOTIVE CATALYST TECHNICAL SERVICE AND APPLICATION ENGINEERING DEPARTMENT; AND JAMES W. DUNHAM, GENERAL MANAGER, UNIVERSAL OIL PRODUCTS CO.; ACCOMPANIED BY DR. VLADIMIR HAENSEL, VICE PRESIDENT, SCIENCE AND TECHNOLOGY

Mr. LEVENTHAL. Mr. Chairman, I will try to be quite brief.

Mr. ROGERS. You had better identify yourself for the reporter.

Mr. LEVENTHAL. On this side of the table are Mr. Robert Leventhal, executive vice president of Engelhard, accompanied by Mr. John Mooney.

I would like to just highlight a very, very short statement.

Mr. ROGERS. Certainly.

Mr. LEVENTHAL. Looking at the situation in terms of national objectives, it would seem beyond debate there are two goals which should be served in an optimum mix: Achieve the maximum conservation of energy resources; clean up the environment, including automotive pollution.

When one cuts through the mass of scientific, pseudoscientific, and nonscientific statements on the subject, it is clear there is only one technology presently available that will achieve both of these objectives, the catalytic converter. In the brief time allocated, I want to summarize just a few key points.

First, as testimony before this committee has confirmed, catalyst-equipped cars use less fuel in meeting emissions standards at whatever level such standards are set. The catalyst permits the engine to be calibrated for maximum efficiency, leaving the resulting emissions to be cleaned up by the catalyst.

Second, if emissions standards are relaxed to levels which can be met by further detuning the engine, the laws of the marketplace will dictate that course of action with additional fuel and driveability penalties. First cost or "sticker price" is understandably a highly important consideration for the auto companies. General Motors, for example, might prefer to equip its cars with catalyst converters. But could it afford to if Chrysler decided not to follow that course?

The answer to this question has already been provided by Mr. Cole, president of General Motors, several times today and also when he testified last month at hearings in the Senate. He said there:

> If the 1974 standards were continued forward with the same certification procedures, we would be compelled to carry over the same hardware in order to be competitive. We are in a free competitive market, and we would be at a cost disadvantage or a price disadvantage if we added extra control equipment, even though we could provide better fuel economy.

Third, adoption of one of the proposals before you; that is, to freeze the 1973–74 emissions standards—and remember 1974 is really the 1973 with one very small change—for several years, would perpetuate the industry's worst fuel economy and driveability years—and it was driveability that Mayor Thomas, a previous witness today, was talking about—while at the same time denying us the improved air quality which is achievable with proven technology.

Fourth, adoption of the proposal to freeze the 1975 interim Federal "49 States standards" for 3 years, allegedly because of the energy crisis, could well worsen the energy crisis. If automobile manufacturers exercise their option to achieve the 1.5 hydrocarbon, 15 carbon monoxide and 3.1 NO_x standards by further engine detuning—as Chrysler and Ford indicated they would try for a portion of their fleets—the 1975, 1976, and 1977 model year cars will be worse with respect to fuel consumption and driveability than the 1973–74 model year cars. Administrator Train has estimated that this would cost an additional 151,000 barrels, more than 6 million gallons, of gasoline every day.

Fifth, if a 2- or 3-year freeze of emissions standards is decided upon by this committee, the far better standard to freeze at would be the 0.9 hydrocarbon and 9 carbon monoxide of the California 1975 interim Federal standard. The fuel savings would be gained because these more stringent standards would foreclose the option of yet another round of engine detuning to control emissions.

A freeze at the 1975 "49 State" interim standard would, as testimony before you today confirmed, for a large portion of some manufacturers' output be met by additional detuning and sacrifice of fuel economy and driveability.

Summarizing, the committee has two choices. It can reject the proposals to amend the automotive provisions of the Clean Air Act and thereby achieve both fuel economy and emissions levels protective of the public health, or it can amend the law and place both these national goals in jeopardy.

Thank you, sir.

Mr. ROGERS. Thank you very much, Mr. Leventhal, for a very concise and informative statement.

Mr. Dunham.

STATEMENT OF JAMES W. DUNHAM

Mr. DUNHAM. Mr. Chairman, I feel like a tail on a very long dog. I am dragging, when I think I should be wagging.

Mr. ROGERS. Well, I am sure we all share that feeling.

Mr. DUNHAM. My name is James W. Dunham. I am the general manager of the Automotive Products Division of Universal Oil Products Co., of Des Plaines, Ill.

I have with me today Dr. Vladimir Haensel, the vice president, science and technology, of UOP. Dr. Haensel is a member of the National Academy of Sciences and has recently received from the President of the United States the National Medal of Science, the Federal Government's highest award for distinguished achievement in science, mathematics, and engineering, for work that he has done in petroleum refining research.

Mr. ROGERS. The committee congratulates you.

Dr. HAENSEL. Thank you.

Mr. DUNHAM. I would like to ask the chairman if the attachments to my brief statement may be included for the record.

Mr. ROGERS. Yes, they will all be included in the record.

Mr. DUNHAM. In view of the limited time available this evening, I will try to restrict myself to the statement of the several points constituting the UOP position on the environment and energy management.

First, we believe strongly that the national objectives for improvement of the environment are completely compatible with an efficient energy management program. [See enclosures A and B, p. 387, this hearing.]

Two, we believe that the reduction of load and other contaminants in gasoline is a health consideration, independent of catalysts. Indeed, the EPA has announced recently its phased objectives for the reduction of lead from gasoline on a nationwide basis. It is my understanding that the program is believed desirable by the EPA whether the catalysts exist or do not exist. The introduction of automotive catalysts for emission control only serves to hasten the introduction of lead-free gasoline. [See enclosure C, p. 418, this hearing.]

Third, the expense of lead elimination from fuel is more than offset by the reduction in automobile maintenance costs available if the lead is removed. A study by the American Oil Co. (enclosure C) indicates a 4- to 5-cent-per-gallon maintenance cost reduction for vehicles using lead-free gasoline. According to this study—

> Eliminating the lead antiknock compounds from the gasoline unquestionably reduces or postpones the need for exhaust system repairs, spark plug replacements, carburetor service, and other gasoline-related maintenance. Moreover, no adverse side effects such as valve seat wear have been observed.

Assuming a maximum of a 10-percent increase in refining costs for lead-free gasoline with a pass-along to the consumer, the effect would be approximately a 1½-cent price increase at the pump. Overall, this still leaves the consumer with a 2½- to 3½-cent cost benefit using lead-free gasoline. Added to the 7-percent average mileage improvement available with catalyst usage, the user achieves an overall 6-plus cent savings per gallon over the life of his automobile.

Let me digress for just a moment, Mr. Chairman, and say that the 7 percent had been derived from the composite of the statements made to the Senate Public Works Committee by the three major automotive manufacturers.

No. 4, it is widely understood that the emission control devices installed in 1974 model year automobiles, including exhaust gas recirculation, spark retardation, and others, have caused substantial penalties to gas mileage and operation. The proposal to proceed with the 1975 interim standards will reduce this gas mileage penalty and yield more efficient energy utilization. Continuation of the 1974 standards, however, would compromise both environmental and energy conservation objectives.

Five, as noted above, implementation of the 1975 interim standards represents progress toward achievement of environment and energy management objectives. When announced, these interim standards received a great deal of attention because they include different and more severe standards for the State of California than for the remainder of the United States. Before extending this two-tiered system for an additional year, we suggest that the Congress and other Federal decisionmakers consider carefully the availability of catalysts now that could permit imposition of the California HC and CO standards countrywide in 1976.

In view of the EPA proposal to defer the 2 gram per mile NO_x standard to the 1977–81 time period, I would suggest consideration of 1976 standards of 0.9 grams per mile HC, 9 grams per mile CO and 3 grams per mile NO_x. With proper utilization of catalysts, these proposed standards will encourage further improvements in gas mileage, additional environmental benefits and conservation of energy.

Six, in conclusion, I want to emphasize the necessity for keeping the research and development momentum for catalysts alive and reaching toward 1977 and beyond. Whereas there are many possible engine improvements on the horizon that may be available in the 1980's on a mass production basis, I think that our nation will want to have effective, durable, and reliable automotive catalysts available for years to come. In this context, industry is generally prepared to invest capital for production facilities in proportion to solid market opportunities.

Leadtime to construct a facility to handle any significant portion of the total U.S. automotive catalyst market is roughly 2 to 3 years, depending upon the availability of critical materials. The investment required is many millions of dollars. It is not likely that the catalyst industry is willing to invest in such major facilities on pure speculation. With the changes that have occurred in this program and which are hinted at in the future, I am concerned, and you may well become concerned, that sufficient production capacity for the products that you will want will not be available when you want them. I urge that we make up our minds, that we stay with a program, and that you give us enough time to prepare to meet the Nation's needs. The only alternative to decisiveness is heavy Government subsidy.

Thank you, sir.

[Testimony resumes on p. 453.]

[Enclosures A, B, and C, and table referred to follow:]

ENCLOSURE A & B

ENERGY AND EMISSION CONTROL

by

Dr. Vladimir Haensel - Vice President-Science & Technology
Universal Oil Products Company

M. J. Sterba - Assistant to the Vice President, Development
UOP Process Division

SUMMARY OF

ENERGY AND EMISSION CONTROL

by

Dr. Vladimir Haensel - Vice President-Science & Technology
Universal Oil Products Company

M. J. Sterba - Assistant to the Vice President, Development
UOP Process Division

The United States needs to define its objectives with respect to the supply and use of energy and environmental controls. In its simplest form the objective would be: "Let us use our energy resources in a most prudent manner and concurrently provide for minimum contamination of our environment." The prudent use and minimum pollution are not incompatible, contrary to a number of official and public statements, and we shall attempt to provide the reasons.

First, let us examine our total energy situation and consider in detail our current problem of gasoline shortage. From the standpoint of energy supply it is not prudent to use either oil or natural gas for electric power generation when coal, atomic energy, hydroelectric or geothermal energy can be utilized. Low sulfur coal will have to be used as the primary energy source until such a time when proper technology is available and installed to remove sulfur dioxide from stack gases. Thus on a short term basis, that is 3-5 years, oil use should be concentrated for transportation and petrochemical purposes, natural gas for home heating and cooking purposes, while low sulfur coal should be used for electric power generation. Within 5 years technology should be available to provide for the large scale removal of sulfur dioxide from coal burning utility operation, thus making it possible to utilize high sulfur coal for that purpose.

Our current gasoline shortage points clearly to misuse of our petroleum resources. For several years newly produced automobiles have been most uneconomical with respect to gasoline consumption due primarily to lower compression ratios, excessive leaning out and greater spark advance retard, as well as an increase in average vehicle weight. Not only are the new cars uneconomical with respect to gasoline mileage, but they also exhibit poorer power response and driveability.

The new cars represent a deliberate choice to lower emissions at the expense of fuel economy, which is inherent in attempting to meet environmental standards while avoiding the use of catalysts. When catalytic converters are employed better mileage and better driveability will be experienced, but we will not regain the pre-emission control economy until we return to higher compression ratio engines. Such engines will require a premium fuel of about 96.5 research octane number. The presence of catalytic converters requires that such a fuel be lead-free. This combination should satisfy the environmentalists, since it will not only reduce the pollution from carbon monoxide and hydrocarbons but also eliminate pollution from lead and its accompanying additives.

The use of catalytic converters to control hydrocarbon and carbon monoxide emissions will be expanded in the future to control oxides of nitrogen. This technological advance will not only reduce the pollution but will further enhance the gasoline economy.

With respect to crude oil requirements to produce the clear gasoline, it has been demonstrated that, if a pool octane number of 96.5 is used in conjunction with high compression ratio engines, the crude oil requirements per mile driven are reduced by 8% relative to the crude oil requirement when a lower octane number fuel is used in conjunction with a lower compression ratio engine vehicle. In addition, studies have shown that the motorist gains the equivalent of some 3-5¢/gallon in maintenance costs due to the use of lead-free fuel.

Over the years, there have been many attacks on the catalytic converter concept. Recently, these attacks centered around the possibility of poisoning from platinum compounds which may be emitted from the converter. Let us put this problem in its proper perspective. Platinum is a noble and expensive metal. It is present in minute quantities on the total catalyst, usually in amounts 1/20 of an ounce or less per vehicle. As a noble metal, it has no capability to form volatile compounds at the reaction conditions, and over the 50,000 miles of operation the losses of the non-poisonous free metals for all the cars in the U.S., if they were equipped with catalytic converters, would be infinitesimally small, totaling less than 40,000 <u>ounces</u> per year. It is paradoxical that we are suddenly confronted by this loss as an intolerable potential danger, while we currently tolerate the emission of more than 250,000 tons of lead compounds from automobile exhaust systems. Studies by the Environmental Protection Agency have indicated serious health concern from this highly toxic pollutant. Other countries have taken much more aggressive steps to eliminate the use of lead.

The latest attack on catalytic converters has been centered on the possible production of sulfuric acid by catalytic converters. Since gasoline contains trace amounts of sulfur compounds, these are converted into sulfur dioxide in the engine. It is now postulated that in the presence of catalytic converters this sulfur dioxide may be converted to sulfur trioxide which, in the presence of water, will give sulfuric acid. This is another ghost, since essentially all sulfur dioxide from any source is converted into sulfur trioxide and, hence, into sulfuric acid before it leaves the atmosphere. The sulfur trioxide from gasoline combustion represents less than one percent of the total sulfur compounds introduced into the atmosphere. Here again the sudden concern about sulfuric acid is paradoxical since we currently tolerate the emission of hundreds of thousands of tons of chlorine and bromine compounds associated with the use of tetra-ethyl lead. Upon combustion and subsequent hydration, the gases from an engine burning leaded gasoline will invariably contain hydrochloric and hydrobromic acids.

The use of catalytic emission control systems on automobiles, especially the second generation 3-component catalytic system, gives this nation its most direct route to a healthy environment with maximum conservation of transportation fuels.

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UOP-1904
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NOTE: Dr. Vladimir Haensel, best known for his contribution to the development of the "Platforming" process for the upgrading of straight run gasoline, is a 1973 recipient of the National Medal of Science. He has also been awarded the Perkin Medal for outstanding work in applied chemistry.

UOP, with yearly gross revenues of approximately $700 million, is a world leader in a number of fields including petroleum refining, petrochemical and chemical production technology and air and water pollution control.

Energy and Emission Control

It has been demonstrated that catalytic systems for the control of automobile exhaust emissions are a technologically and economically sound way to improve air quality. Furthermore, it is reasonably certain that the Federal Air Quality Standards eventually adopted will be stringent enough to require the use of catalytic converters on a substantial percentage of automobiles. Since catalytic converters require the use of unleaded gasoline, a statement is appropriate regarding the complex interrelationship of energy supply, of the economics of using unleaded gasoline, and of emission control.

A study has been made to establish the cost of production of a lead free gasoline pool[1]. This study indicates that the additional refining cost is in the range of 0.95-1.5 cents per gallon of gasoline. The spread depends largely on accounting methods, pricing structures and on the manner of revising processing steps. The study further shows that in view of maintenance savings the motorist will gain 3 to 4 cents per gallon[2]. Thus, whatever additional costs of deleading are passed on to the motorist they will be more than compensated for by the savings.

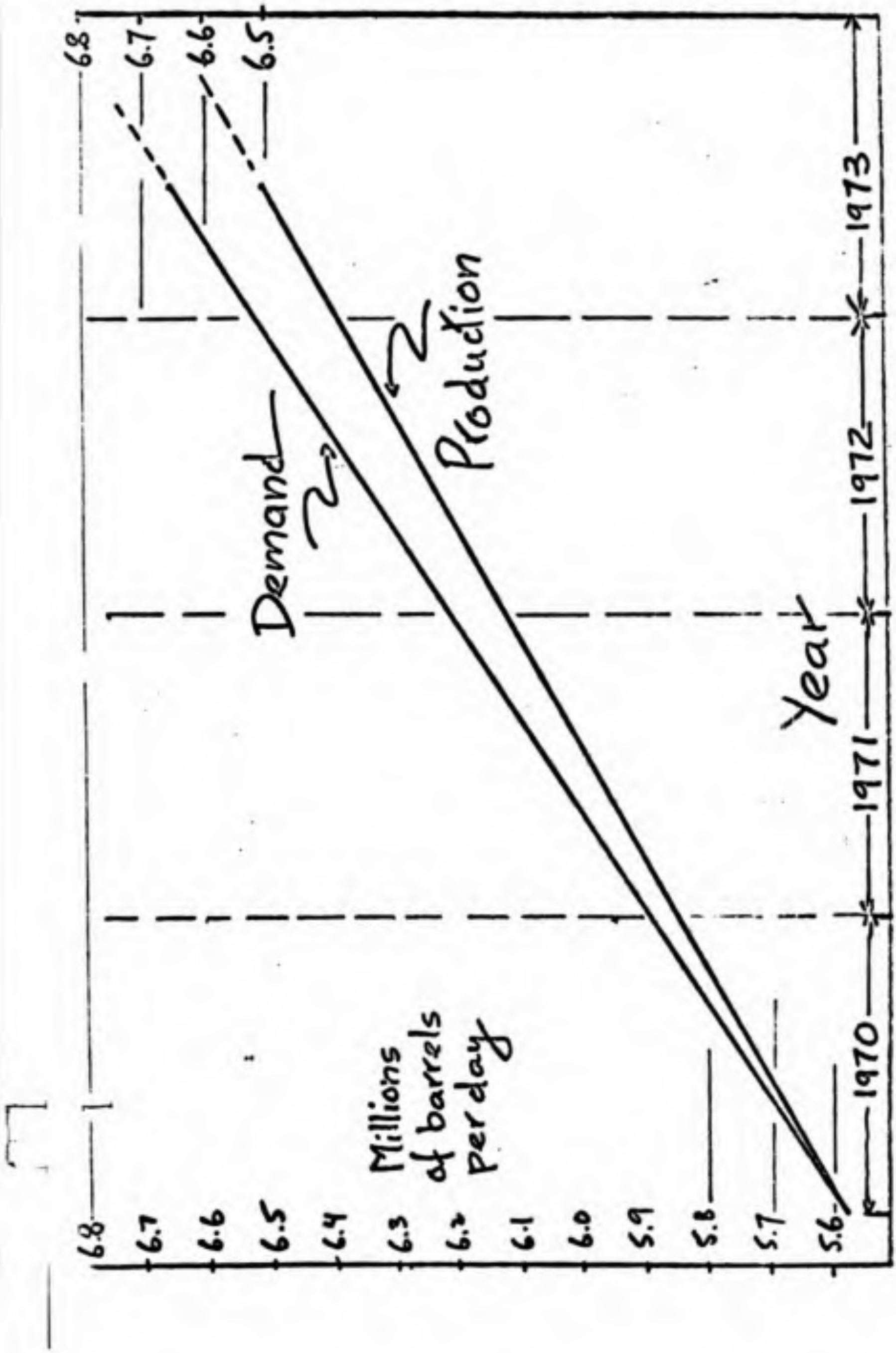
The next question is that of energy loss incurred in the conversion to the lead free gasoline pool. Studies indicate that in order to make the same volume of gasoline of equivalent octane number, an additional 4% of crude must be processed. This additional 4% of crude does not mean a 4% energy loss, it merely means that in the course of refinery operation the 4% has been converted to products other than gasoline, in this case largely substitute natural gas, or a refinery energy source.

Thus, the conclusion is that to the motorist there is a net saving by using lead-free gasolines and that from the national standpoint there is no energy loss.

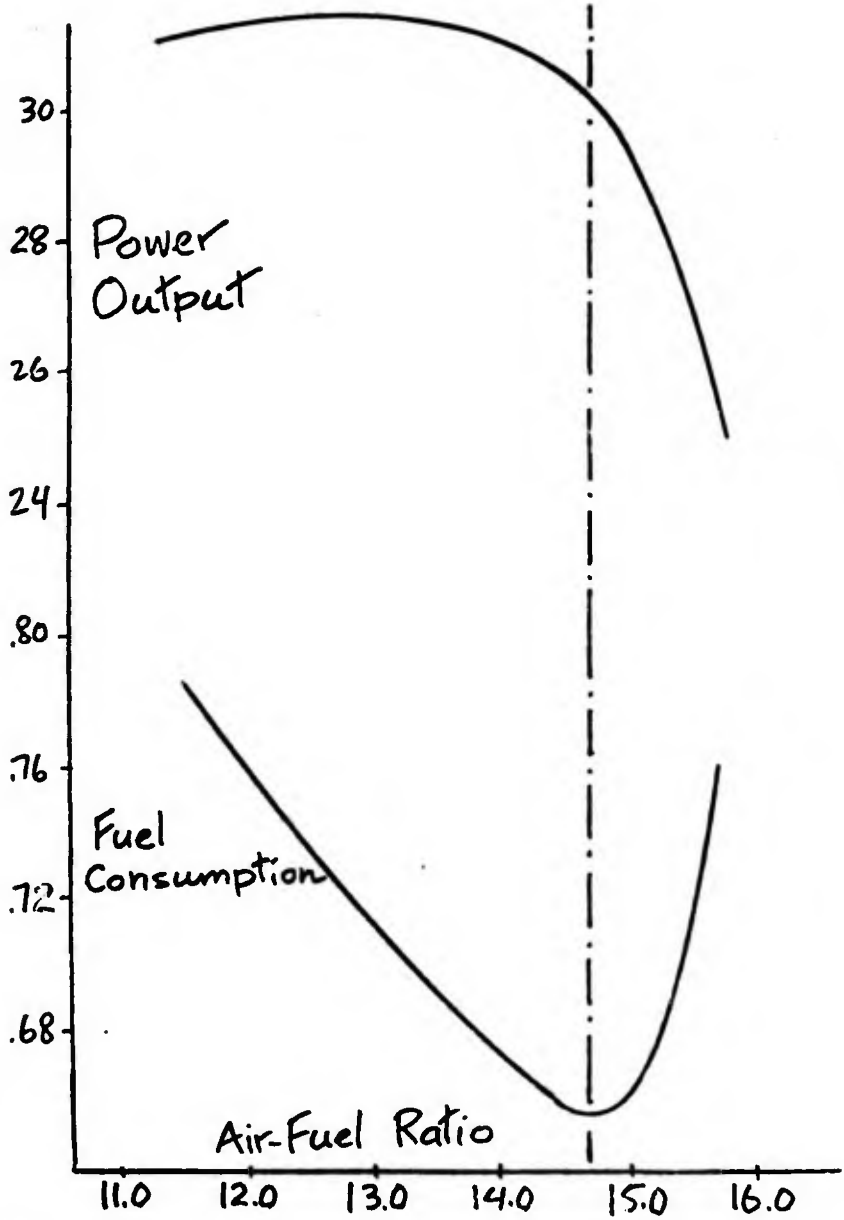
Let us now examine in greater detail the problem of energy supply, particularly with respect to gasoline. The attached graph (page 3) indicates the gasoline production and gasoline demand. The data are based on American Petroleum Institute weekly averages and Bureau of Mines information[3]. The data clearly show that the increased demand has outstripped the supply by a substantial margin. In preparing the graph, the month by month data for production and demand were used in a least square calculation to obtain a straight line relationship. It will be observed from the graph that over the last 41 months starting with January 1970, when demand and production were reasonably even, to May 1973, the gasoline demand has grown by 1.08 million barrels per day, while production has increased by 0.93 million barrels per day, representing a current deficit of 150,000 barrels per day. It is estimated that by the end of 1973 the deficit will reach 200,000 barrels per day. Thus, unless the rate of production is increased or the rate of demand is checked, the gasoline stocks, relative to prior years, will be depleted by nearly 30% by the end of 1973. The trend is quite obvious from the following table:

(1) Month & Year	(2) Demand in million barrels/day	(3) Stocks in million barrels	Days of reserve Col (3)/Col.(2)
May 1970	5.86	221.3	38
May 1971	5.90	221.7	38
May 1972	6.45	214.7	33
May 1973	6.89	198.4	29

UOP's Marketing Services indicate that: "Looking ahead, it appears that the summer of 1973 can be weathered with minimum difficulty (localized dislocation will be prevalent, however). The really serious problem in gasoline supply will occur in 1974. Serious difficulties on fuel oil supply will probably emerge in the 1973-74 heating season."


Millions of barrels per day
6.8
6.7
6.6
6.5
6.4
6.3
6.2
6.1
6.0
5.9
5.8
5.7
5.6
Demand
Production
Year
1970
1971
1972
1973

This increase in demand is only partly due to the increased car population. Most of it is due to the poor gasoline mileage economy of newer automobiles. This poor gasoline economy is due to a number of factors. The EPA in its report entitled, "EPA Report on Fuel Economy and Emission Control, November 1972"[4], has documented the economy losses due to the increased weight of the average American automobile and the use of power consuming options such as air conditioning, automatic transmission and power accessories. Another part of the lost economy is due to tighter emission controls which have led to the use of leaner air/fuel ratios and lower compression ratios. Both of these lead to lost efficiency in utilizing fuel energy. Let us examine the factors which contribute to the reduced efficiency. The following graph (page 5) illustrates the relationship of power output and fuel consumption versus air-fuel ratio. At an air-fuel ratio of 14.7 weights of air to 1 weight of fuel there is exactly the right amount of air required to burn all of the gasoline. To the left of this point, called the stoichiometric point, the engine operates on the rich side, that is, there is insufficient air to burn all of the fuel. To the right of this point the engine operates on the lean side, that is the engine is supplied with more than the required amount of air to burn the fuel. One can see from the graph that the maximum power output from the engine occurs at a broadly rich condition, while the maximum efficiency, that is minimum fuel consumption, occurs at a slightly lean condition. In other words, a good combination of driveability, with respect to power response, and economy occur at near the stoichiometric air fuel ratio. It will be noted also that the power output diminishes rapidly as a given engine is operated more and more lean. With the advent of progressively tighter emission standards, the automobile companies have gone to the leaner side of engine operation in order to insure a greater supply of air relative to fuel so that the carbon monoxide and hydrocarbons could be burned more completely. This has resulted in poorer fuel economy and, at the same time,


30
28
26
24
.80
.76
.72
.68
Power
Output
Fuel
Consumption
Air-Fuel Ratio
11.0
12.0
13.0
14.0
15.0
16.0

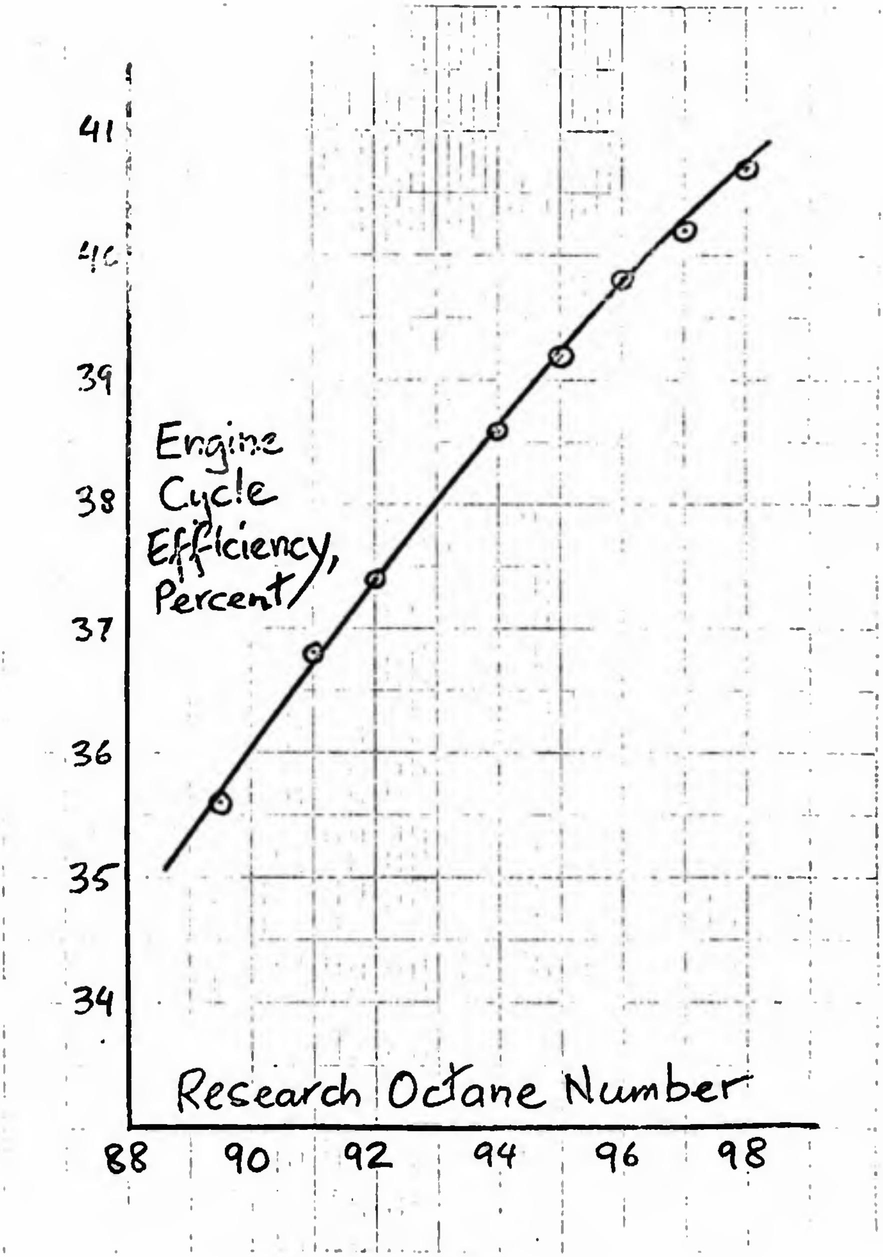
UOP

since it also gives a poorer power response, the driver tends to utilize power enrichment more frequently. This in turn produces an even greater fuel penalty. Thus, it is quite apparent that leaned out cars do tend to run under conditions of reduced gasoline mileage.

Let us now go a step further. The anticipation of the use of catalytic converters for exhaust emission control has dictated the use of lead-free fuels. The oil industry cannot change overnight to produce both premium and regular grades of lead-free gasoline, but it can produce a lead-free regular gasoline much more readily. In fact, effective July 1974, every service station will be required to sell lead free regular gasoline, and currently a number of oil companies are offering such a fuel. The use of a regular gasoline having a Research Octane Number of 91 requires the use of a lower compression ratio engine to avoid knocking. This is an advantage from the standpoint of pollution control in that it will reduce the amount of nitrogen oxides formed during the combustion process. It so happens that the amount of nitrogen oxides (NO_x) formed depends on the temperature in the combustion zone. The higher the temperature, the more nitrogen oxides are formed. As the compression ratio is reduced, the combustion temperature is reduced and less nitrogen oxides are produced. In addition, as the engine is deviating appreciably from the stoichiometric point, the NO_x formation is also reduced. In a further move to minimize the NO_x formation, the automobile companies have retarded the spark advance so that a maximum pressure and maximum temperature are not reached. This results in an effect similar to that of a reduced compression ratio and thus also produces a loss in power and poorer economy.

This sounds like a perfectly proper approach in anticipation of the exhaust emission standards, however, let us examine what it does to our gasoline supply picture. We already know that operating the engine on the lean side imposes a fuel penalty and now let us find out how the reduction in compression ratio affects the fuel economy, since nearly all of the new cars are capable of using regular gasoline. T. O. Wagner and L. W. Russum in a recent API paper[5] state that: "Although many features of engine design affect vehicle efficiency and octane requirements, we chose compression ratio as the defining variable because it has a larger effect, overall, than any other single feature."

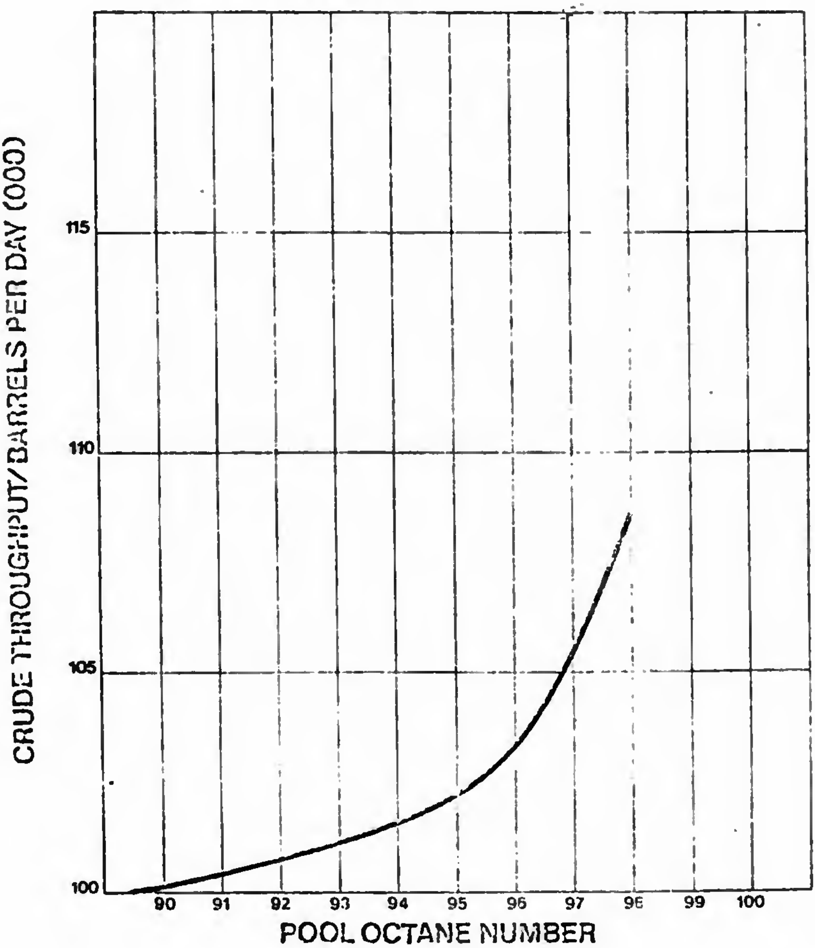
The following graph (page 8) shows the relationship between Research Octane Number of the fuel and the engine cycle efficiency. In constructing this graph, we used the data of Wagner and Russum, who calculated the cycle efficiency at an average of "cruise" and "acceleration" modes. It should be stated that the higher the octane number the higher the compression ratio that can be used. As the compression ratio is increased a higher combustion temperature is reached and the engine operates more efficiently, since a higher pressure is exerted on the piston. It will be observed that over the range of 89.5 to 98 Research Octane Number the combustion efficiency is increased from 35.6 to 40.7%, representing a 14% increase in power output, or, conversely for the same power output, we need to use only 87.5% of the fuel. Let us now relate this to what this does to our gasoline supply picture, since, as indicated earlier, the production of a higher octane gasoline does involve the processing of more crude to give the same volume of gasoline. This is shown on the graph (page 9)[6]. This graph confirms our earlier statement which indicated that in order to make the same pool octane number lead free product as is now made with lead, about 4% more crude processing is required. The next step is to put the two relationships together, that is, the reduced gasoline consumption through the use of a higher compression ratio engine and the increased crude demand for making this higher octane number lead-free gasoline. This relationship is shown on the graph (page 10). It will be observed that in the range of 96-96.5 Research Octane Number the crude requirement to drive automobiles equal distance reaches a minimum of 92.4% of the requirement of the base case of 89.5 Research Octane Number. Beyond this minimum point the crude requirement curve increases more

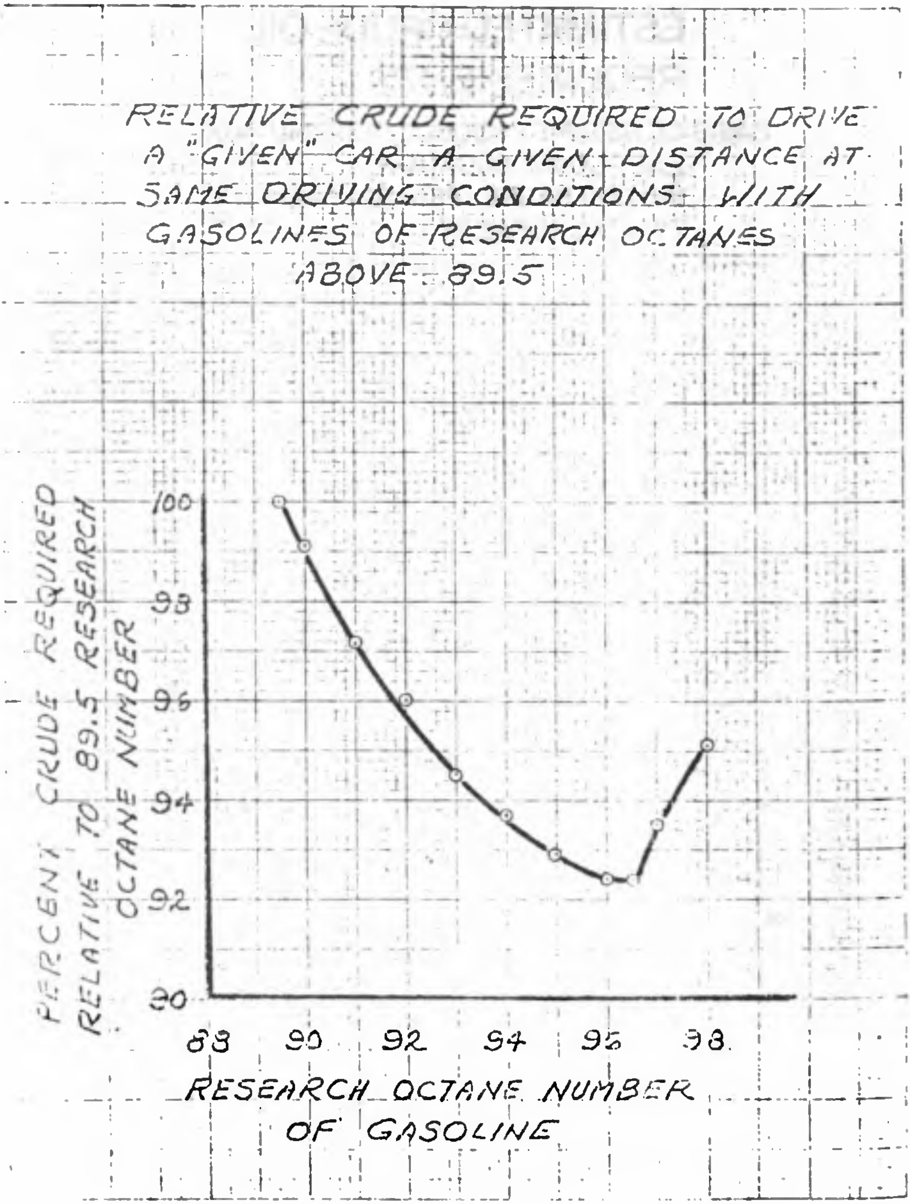


Engine Cycle Efficiency, Percent
41
40
39
38
37
36
35
34
Research Octane Number
88
90
92
94
96
98

ESTIMATED CRUDE OIL REQUIREMENTS

BASIS: CONSTANT PRODUCT DISTRIBUTION
EAST COAST LOCATION
100,000 BARREL PER/DAY CAPACITY
TYPICAL REFINERY

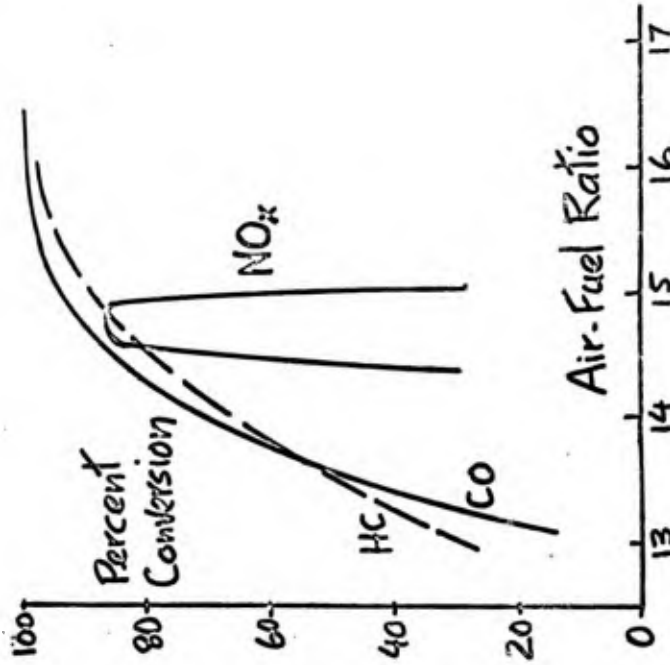



RELATIVE CRUDE REQUIRED TO DRIVE A "GIVEN" CAR A GIVEN DISTANCE AT SAME DRIVING CONDITIONS WITH GASOLINES OF RESEARCH OCTANES ABOVE 89.5
PERCENT CRUDE REQUIRED RELATIVE TO 89.5 RESEARCH OCTANE NUMBER
100
98
96
94
92
90
88
90
92
94
96
98
RESEARCH OCTANE NUMBER OF GASOLINE

rapidly than the increase in engine cycle efficiency and more crude throughput will be needed, however, even this requirement is considerably below the requirement of our base case of 89.5 Research Octane Number.

It should be pointed out that in addition to this reduced crude requirement efforts should be made to improve it still further. It is believed that the extent of current practice of operating quite lean should be changed to operating much closer to the stoichiometric point, which does produce close to maximum power and therefore driveability as well as the optimum fuel economy. In addition, the use of spark advance retardation, as practiced now, should be discontinued in view of its effect on power output and fuel economy.

What do these recommendations do to the problem of emission control? Have we merely indicated a way to alleviate the problem of gasoline shortage and aggravated the emission problem which is partly responsible for the gasoline shortage to begin with? The answer is that these recommendations not only point the way to better driveability and fuel economy but they also point the way to better exhaust emission control. Extensive tests have shown that at the stoichiometric air/fuel ratio it is possible to control HC, CO and NO_x simultaneously in a single catalyst bed without the use of supplemental air. This is shown in the graph (page 12). It will be observed that there is a "window" where the very high conversions of NO_x are attained by the interaction with carbon monoxide in the presence of the same catalyst. The width of this "window" varies with the catalyst. Considerable advances have been made in widening the "window" in order to allow for some material fluctuations in the air-fuel ratio in actual driving. Building further on this observation, progress is being made in developing a feedback control system capable of maintaining stoichiometric conditions over all engine operating modes and regardless of ambient temperature,


Percent Conversion
HC
CO
NOx
Air-Fuel Ratio
0
20
40
60
80
100
13
14
15
16
17

barometric pressure, humidity or fuel composition. This control system will create a self-tuning automobile which, operated on high octane, unleaded fuel, will provide maximum emission control, maximum energy utilization and maximum driver satisfaction at minimum expense.

Vladimir Haensel & M. J. Sterba
June 25, 1973

Bibliography

[1]Summary of Statement of John O. Logan and C. G. Gerhold of Universal Oil Products Company, Des Plaines, Illinois to House Subcommittee on Public Health & Welfare, Washington, D.C., March 20, 1970.

[2]Testimony before the Subcommittee on Public Health & Welfare of the Commission on Interstate & Foreign Commerce, Washington, D.C., Robert C. Gunness, President, Standard Oil Company (Indiana), March . 1970.

[3]Monthly Bureau of Mines Minerals Industry Surveys. Also American Petroleum Institute weekly averages as published in the Oil and Gas Journal.

[4]"Fuel Economy and Emission Control", U. S. Environmental Protection Agency, Office of Air & Water Program, Mobile Source Pollution Control Program, November, 1972.

[5]"Optimum Octane Number for Unleaded Gasoline", by T. . Wagner and L. W. Russum, Amoco Oil Company, presented at 38th Midyear Meeting of the American Petroleum Institute, Philadelphia, Pa., May 15, 1973.

[6]Summary of Statement of C. G. Gerhold, Universal Oil Products Company, Des Plaines, Illinois, to the Assembly Standing Committee on Transportation of State of New York, New York City, N. Y., September 17, 1970.

Energy and Emission Control

Supplemental Statement No. 1

With crude oil, gasoline and other fuels in short supply in the United States, it becomes of interest to study ways in which a given automobile transportation task can be accomplished with a minimum of fuel consumption. The use of catalytic converters, which may be necessary to meet eventual Federal Air Quality Standards, will very likely require the use of unleaded gasoline. Therefore this discussion will be directed at a determination of that unleaded gasoline octane number corresponding to the minimum crude oil usage.

That there should be such a minimum is the result of two opposing trends. One trend is the requirement of less fuel to move a given vehicle under constant driving conditions over a given distance, as the compression ratio of the engine of this defined vehicle is increased within reasonable limits. However, this rise in the compression ratio of the engine requires the use of gasolines having higher octane ratings. But to manufacture gasolines having higher octane ratings along with a constant amount of all other refinery products, requires increasing amounts of crude oil. With the simplifying assumption of the constant vehicle driven under constant conditions over a given distance, a minimum crude requirement can be sought as a result of the above described opposing trends. Similarly, a minimum overall fuel or energy cost might be computed, but this is not considered in this development.

The minimum crude requirement, corresponding to the optimum gasoline octane number was established by a sequence of four computational steps:

1. First, the engine octane number requirement was defined in terms of its compression ratio.

2. Then the vehicle efficiency with respect to fuel usage was related to the compression ratio of its engine.

3. As a third step the crude oil requirement was computed for producing fixed quantities of refinery fuel products, with the gasoline having a variable octane number.

4. Finally, the opposing trends of steps (2) and (3) were related to each other to establish a minimum crude oil requirement, and at what octane number this minimum occurred.

Compression Ratio and Octane Number Requirements

To establish the permissible engine compression ratios for a range of gasoline octane numbers, reference was made to the work of Wagner and Russum of Amoco who reported their results in a paper[1] "Optimum Octane Number for Unleaded Fuel" presented at the May, 1973 meeting of the American Petroleum Institute. These authors derived the above relationship from surveys of octane number requirements of automobiles conducted by CRC (Coordinating Research Council) between the years 1956 and 1972. In the regression analysis of the CRC data, they derived empirical relationships for both Research and Motor Octane Numbers, although only the former will be used in this discussion.

For Research Octane Numbers, their relationship was expressed by the following equation:

$$RONR = 66.4 + 2.95 (CR)$$

where RONR = Research Octane Number Requirement

CR = Engine Compression Ratio

Although unleaded fuels were used only in 1971 and 1972 in the CRC surveys, it is assumed that the above equation is generally applicable to unleaded gasoline octane numbers over the range of 89.5 to 98.

The first column in Table 1 is a range of Research Octane Numbers in increments of one unit. Included are reference points of 89.5 (the present unleaded octane number of the national gasoline pool) and 96.5 (the present leaded octane number of the national pool). Using the above equation, the maximum permissible compression ratios corresponding to each octane number were computed, and appear in the second column of the table. Because many factors other than compression ratio affect the octane requirement of an engine, the equation used represents a statistical average of the automobiles represented in the survey.

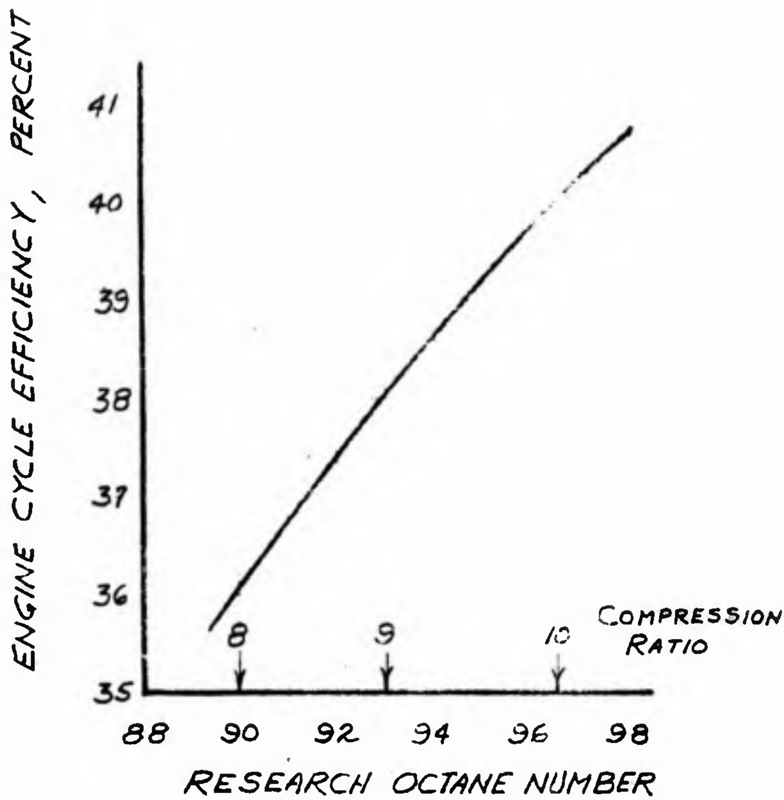
Vehicle Efficiency Related to Engine Compression Ratio

Engine fuel-air cycle efficiencies, as related to compression ratios and appearing in the third column of Table 1, were taken directly from the paper of Wagner and Russum who used a classical method of computation and state that ". . . it yields results more reliable than experimental methods." These authors computed efficiencies for full-throttle and for part-throttle conditions. At each throttle setting efficiency calculations were made for lean, stoichiometric and for rich fuel/air ratios. They plotted cycle efficiencies against compression ratios for two combinations of throttle setting and fuel/air mixture ratios: a "cruise" mode (part throttle and lean mixture), and an "acceleration" mode (full throttle and rich mixture), as representing the dominant modes of engine operation. They point out that the relative engine cycle efficiencies between any two compression ratios is nearly the same for either of the above sets of conditions, and conclude that ". . . the intrinsic benefit of raising compression ratio is practically the same for all operating modes." The engine cycle efficiencies in the "acceleration" mode listed in the third column of Table 1 were read directly from their Figure 1, as related to compression ratios. How the engine cycle efficiency is related to the gasoline octane number through the permissible compression ratio is displayed on Figure 1. Both octane number and the compression ratio it permits are indicated along the horizontal axis of the plot.

Wagner and Russum then point out that errors are negligible in assuming that for a given vehicle, the overall vehicle efficiency (the work output at the

FIGURE 1

ENGINE CYCLE EFFICIENCY
RELATED TO
GASOLINE OCTANE NUMBER



wheels per fuel energy input to the engine) is directly proportional to engine cycle efficiencies at each compression ratio.

The fuel required to propel a given vehicle under a given set of driving conditions over a given route is, then, inversely proportional to its engine cycle efficiency. In Table 1, the fourth column shows the fuel consumption required to perform this task relative to the amount of fuel needed at the reference base point octane number of 89.5.

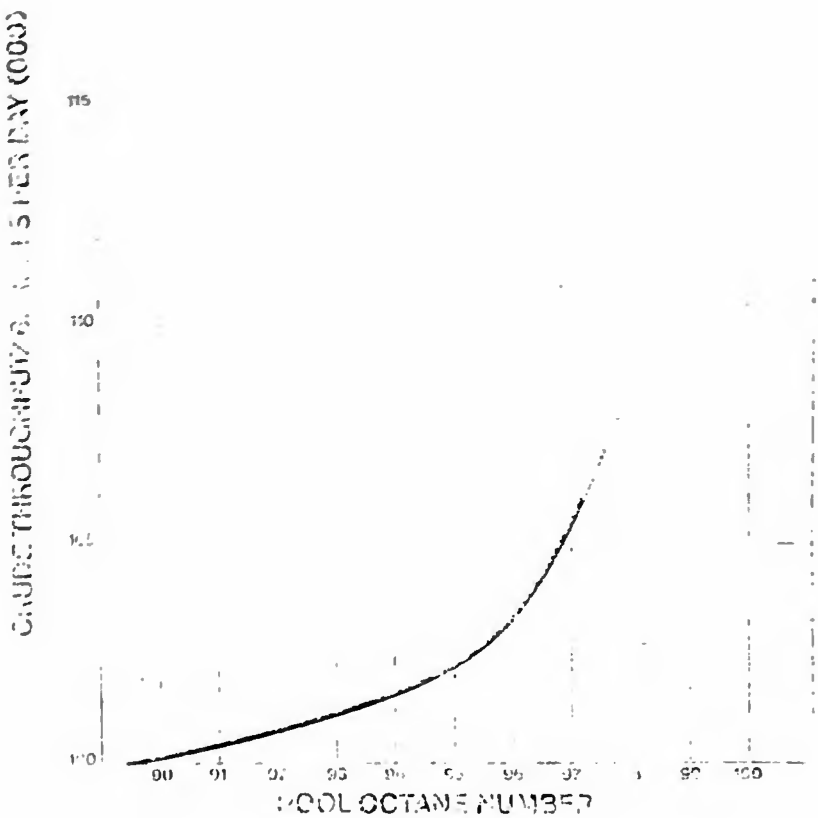
<u>Crude Required to Produce Higher Unleaded Gasoline Octane Numbers</u>

The relationship between crude throughput and the unleaded Research Octane Number of the pool gasoline shown in Figure 2 was derived by making nine sets of sequential refinery model computations. As a base case, a flow scheme model was established for a typical 100,000 barrel per day refinery which made product yields representative of the average output of the U.S. refining industry. The gasoline pool, about 40% premium and 60% regular, had a nominal Research Octane Number of 96.5 with 2.5 grams per gallon of lead. Without lead, this gasoline pool had an octane number of 89.5. These octane numbers and lead contents are typical of the U.S. refinery output during the last several years.

Following the definition of the base case as established above, a sequence of eight sets of computations was performed by modifying the base case model to make the same quantity of each refinery liquid product, but with unleaded pool gasoline octane numbers set at successively higher values above the base case value of 89.5. The base case was modified for the higher octane models by operating certain existing or expanded processing units at higher severity, by rearranging the flow scheme, and by the insertion of additional but commercially proven processing units, as required to achieve the objective gasoline pool octane number. Each case was optimized by linear programming techniques to show lowest manufacturing costs within the constraints of available technology.

ESTIMATED CRUDE OIL REQUIREMENTS

BASIS: CONSTANT PRODUCT DISTRIBUTION
EAST COAST LOCATION
100 000 BARREL PER/DAY CAPACITY
TYPICAL REFINERY



The increasing crude oil requirements for the successive cases of ascending pool gasoline octane numbers was plotted to form the smoothed curve on Figure 2 which shows a rather sharply rising crude requirement as the octane number rises much above 95-96. Thus, when 100 barrels of crude oil are needed to make a gasoline pool of 89.5 octane number, about 102 barrels are required to make 95 octane number, but a pool octane number of 97 needs 105 barrels of crude. Numerical values of crude requirements as related to unleaded gasoline pool octane numbers appear in column five of Table 1.

Of the incremental additional crude oil required to make the higher octane number unleaded gasoline pools above 89.5, a small portion is used to supply the additional energy requirements needed to operate the processing units to create the higher octane numbers. At the higher octane numbers, in the vicinity of 97, about one-fourth of the additional crude is used to supply this extra energy which includes fuel to fire process heaters, to raise steam, and to produce the extra electrical power. More nearly one-tenth of the supplemental crude is needed to supply extra energy requirements at the lower octane levels just above 89.5. The remainder of the additional crude, not used to produce refining energy, is converted by the more severe processing to light hydrocarbons, principally LPG (C_3 and C_4), and some C_2 and methane. These light hydrocarbons are useful and salable products, available to aid in supplying the energy needs of the nation.

In the computations the produced amounts of gasoline, distillate fuels, residual fuels and other liquid refinery products were held constant as the octane number of the gasoline pool was changed.

Crude Oil Requirement Versus Unleaded Octane Number

It is seen from Table 1 that as the unleaded octane number (column 1) is increased above the base of 89.5, the relative amount of crude required to produce these gasoline octane numbers increases (column 5), but because higher engine compression ratios (column 2) are premissible, the relative amount of fuel derived as a fixed yield from crude diminishes as shown in column 4. Thus when a given car is equipped with an engine to take advantage of the higher octane number, the overall crude requirement shown in column 6 of Table 1 is the product of the numbers in columns 4 and 5. The relative amount of crude is seen to diminish as the octane number is raised above the base value of 89.5, so that a minimum crude oil requirement is reached at an unleaded octane number of 96-96.5, above which the needed crude increases. These overall trends are shown on the plot of Figure 3 which displays this minimum point in crude requirement.

It is interesting that Wagner and Russum[2] came to a similar conclusion, based on an economic approach. They state that "Motorist's total gasoline costs per mile are lowest when the octane number of the unleaded gasoline pool is in the range of 85 to 87 Motor Octane number." These Motor octanes correspond to Research octanes in the vicinity of 95 to 97.

Another study, reported by W. R. Epperly[3] of Exxon, on the matter of crude conservation and minimum cost to the motorist relates that ". . . we have concluded the net value to the customer is higher with high octane fuel than with low octane fuel. We have also found that for clear fuels, when fuel consumption is taken into account, crude run decreases with increasing octane at least up to 97 RON pool as shown here."

M. J. Sterba - July 10, 1973

FIGURE 3

RELATIVE CRUDE OIL REQUIRED TO DRIVE A "GIVEN" CAR OVER A GIVEN DISTANCE AT SAME DRIVING CONDITIONS WITH GASOLINES OF UNLEADED RESEARCH OCTANES ABOVE 89.5

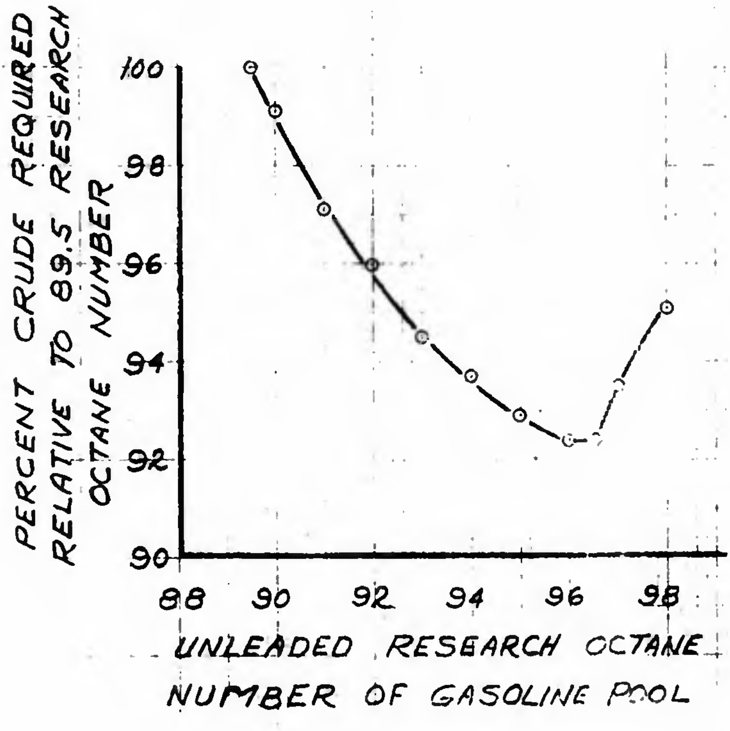


Table 1

Relative Crude Required to Drive a Given Car a Given Distance at Same Driving Conditions with Gasolines of Research Octane Numbers above 89.5

(1) Unleaded Gasoline Research O.N.	(2) Permissible Compression Ratio[a]	(3) Engine Cycle Eff.,%[b]	(4) Relative Fuel Consumption for Driving[c]	(5) Relative Crude Required for O.N.[d]	(6) Crude Required to Drive Car Equal Distance[e]
89.5	7.85	35.6	1.000	100.0	100.0
90	8.0	36.0	0.989	100.2	99.1
91	8.35	36.8	0.967	100.4	97.1
92	8.65	37.4	0.952	100.[illegible]	96.0
93	9.0	38.1	0.934	101.[illegible]	94.5
94	9.3	38.6	0.922	101.[illegible]	93.7
95	9.6	39.2	0.908	102.3	92.9
96	9.9	39.8	0.894	103.[illegible]	92.4
96.5	10.02	40.1	0.888	104.[illegible]	92.4
97	10.15	40.2	0.886	105.[illegible]	93.5
98	10.4	40.7	0.875	108.[illegible]	95.1

(a) From RON = 66.4 + 2.95 (CR): Wagner & Russum.

(b) From Fig. 1 ("Acceleration" Mode): Wagner & Russum

(c) Based on 100% at 89.5 RON

(d) Crude required at Refinery to make clear RON, based on 100% at 89.5 RON.

(e) = (c) x (d). Assumes same driving conditions with "same" cars of varying CR only. Percent relative to 100 at base RON of 89.5.

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[2] Summary of Statement of C. G. Gerhold, Universal Oil Products Company, Des Plaines, Illinois, to the Assembly Standing Committee on Transportation of State of New York, New York City, N.Y., September 17, 1970.

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ENCLOSURE C

CATALYST, FUEL CONSERVATION AND THE ENVIRONMENT YESTERDAY, TODAY AND TOMORROW

The current controversy over automotive oxidation catalysts is reminiscent of the birth and maturing of other technological advances. In 1948 UOP introduced Platforming, an advanced refining process utilizing platinum catalyst. The petroleum industry scoffed and said it was too expensive. Today, 25 years later, our many customers are satisfied and our competition is selling similar processes.

Ever since its infancy in the late 1950's to its current maturity, the history of the development of catalytic emission control devices has moved from one anticlimax to another. Catalysts have been singled out for criticism again and again primarily because they are the only practical way now available for achieving the automobile emission standards and timetable of the 1970 Clean Air Act. Not surprisingly, the more distant solutions frequently look better because less is known of their shortcomings. We at UOP believe the only realistic way to look at automotive pollution today is to accept the present gasoline fueled internal combustion engine as a fact of life.

In the next few pages, we will try to put the current situation in perspective. This paper will deal briefly with: Yesterday's technology of engine modification and how it curbed pollution and its effect on fuel conservation; today's catalytic devices and what effect they will have on pollution and fuel supplies; and, what we can expect from tomorrow's technology - the second generation of catalytic device systems.

YESTERDAY

During the 1960's automotive exhaust became recognized as a major contributor to air pollution. From this realization came the Clean Air Act of 1970 that called for the regulation of automotive emissions. This act set automotive emission standards, which in combination with other planned emission reductions would achieve clean, healthful air for the nation. The Clean Air Act also charted a course for the gradual reduction of automotive emissions that started in 1970 and was to end in 1976 with low emissions required to assure the desired ambient air quality. At the time of writing the Clean Air Act, it was foreseen that the 1976 emission standards would be technically difficult to achieve. For the first year of emission regulation, only modest reductions of HC and CO were mandated and were easily accomplished by simple engine modifications. These initial engine modifications caused performance and economy to suffer slightly and NOx emissions to increase. Later, when NOx reductions were mandated along with further HC and CO reductions, it became necessary to add spark retard and exhaust gas recirculation. Put together, all of these engine modifications have now resulted in significant reduction of fuel economy, estimated by the EPA at about 7% and at 10% to 13% by the car manufacturers.

Yesterday's technology of engine modification has achieved significant reductions in the three major pollutants from pre-controlled cars: hydrocarbon - 80%, carbon monoxide - 70% and oxides of nitrogen - 40%. However, further emission reductions are necessary and they must be coupled with gasoline economy because of the fuel shortage.

TODAY

It is generally accepted, though sometimes unwillingly, that oxidation catalysts are the only available way of meeting the stricter hydrocarbon and carbon monoxide standards and, indirectly, the oxides of nitrogen standards. In evaluating the future of oxidation catalysts, we at UOP believe it should be viewed in two ways: First, the indirect benefits and secondly, what the catalyst itself does.

Indirect Benefits

Increased Gasoline Mileage

The catalyst itself does not measurably affect gasoline mileage, but it does allow the engine to be modified to improve mileage. Changes in timing, EGR and fuel mixture can be made in 1975 models. As a result, the motorist will save money and less total gasoline will be consumed. We estimate the fuel penalties can be decreased from the high of 10% in 1974 to 3% in 1975.[1]

Improved Performance

The 1973 and 1974 model cars suffer by comparison with earlier years in performance. The 1975 models with catalytic converters will have significantly better starting and acceleration characteristics.

Decreased Lead and Halogen Compounds

The combustion of gasoline with tetra-ethyl lead in motor vehicles produces over 90% of the lead in the atmosphere. These lead compounds may be highly toxic. In order to prevent the accumulation of lead deposits on vital

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[1]Based on auto manufacturers' submissions to the Senate Public Works Committee, November 5, 1973.

engine parts, halogenic compounds or scavangers are also added to the gasoline. These produce hydrochloric and hydrobromic acids in the exhaust. Lead is a poison for catalysts, and future gasoline will be produced without lead. This fact coupled with the health hazard will eventually lead to the elimination of practically all airborne lead.

<u>Lower Maintanance</u>

By using lead-free gasoline, the motorist will save on maintenance. Exhaust system repairs, spark plug replacement and carburetor servicing will be reduced. This could save the motorist up to an average of 5¢ per gallon.[1]

What the Converter Does

<u>Hydrocarbon and Carbon Monoxide Reductions</u>

In earlier testimony to the EPA, we described the results of a 50,000 mile durability and abuse test.[2] At 50,000 miles all hydrocarbon emissions were less than 0.3 grams per mile and all carbon monoxide less than 2.2 grams per mile, considerably below the original 1975 standard of 0.41 and 3.4 respectively.

<u>Reactive Hydrocarbon Reduction</u>

Catalysts have the unique ability to selectively remove the reactive hydrocarbons that are responsible for photochemical smog. If we assume that the average 1975 automobile without catalysts will emit 1.2 grams of hydrocarbon per mile, then about 0.78 grams or 65% of this will be reactive and will be capable

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[1]Society of Automotive Engineers Paper No. 720084, January, 1972 (attached)

[2]50,000 Mile Standard Durability Tests and Abuse Durability Tests Using 260 Cu. In. Reactors and Palleted Catalyst (attached)

of forming photochemical smog. The average 1975 car equipped with catalysts will emit about 0.3 grams per mile of hydrocarbons. Of this, about 0.15 grams will be reactive. Therefore, 1975 cars with catalysts will emit only about 20% of the quantity of reactive hydrocarbon emissions as 1975 cars without catalysts.

Polynuclear Aromatic Hydrocarbons Reduction

The effectiveness of catalytic converters in removing reactive hydrocarbons is important to people concerned about the presence of polynuclear aromatic hydrocarbons (PNAH) in automobile exhaust. These "tars" are suspected of having carcinogenic, or cancer-producing, properties. Fortunately, catalytic converters are about 95% effective in removing them. Numerically speaking, typical automobile exhaust contains one part of PNAH per ten million parts of exhaust. After passing through a catalytic converter, this is reduced to about five parts per billion. To put these tiny quantities in perspective, let's compare the PNAH "tars" in exhaust to the similar "tars" in a cigarette. The smoke from one cigarette contains about 18 milligrams of tar. Raw exhaust emitted from an engine in one hour contains only 10 milligrams, or about half as much. After passing through a catalytic converter it would contain only 0.5 milligrams of tar.

Oxides of Nitrogen

In any mode of operation, the catalytic converter system never increases the quantity of nitrogen oxides. Interestingly enough, an oxidation catalyst when fed with an exhaust gas of stoichiometric proportions will reduce the nitrogen oxides concurrently with the oxidation of hydrocarbons and carbon monoxide.

<u>Oxides of Sulfur</u>

The presence of sulfur compounds in the atmosphere has been a concern ever since the use of coal and the smelting of metal sulfide ores started more than 1,000 years ago. The post World War II sulfur smog episodes in various parts of the world accelerated the study of and attention to sulfur emissions. The main sources of sulfur compounds in the atmosphere are biological decay, ocean sprey, and the combustion of fossil fuels. The burning of fossil fuels has increased rapidly with increased population and industrialization and now accounts for about one-third of the total sulfur emitted to the atmosphere. Most of this is naturally oxidized in the atmosphere to sulfur trioxide in a short time. The sulfur is then removed from the atmosphere via the formation of sulfuric acid and its salts which are purged by rain and gravitational settling. Thus, in the total view, it makes little difference in what form the sulfur is emitted to the atmosphere.

Presently, in the United States less than 1% of the total sulfur emissions come from the combustion of gasoline in automobiles. The sulfur level in the fuel defines the amount of sulfur dioxide and sulfur trioxide produced by the engine. The sulfur content of most gasolines now range between .01 and .08 weight percent which is about the same order of magnitude as the halogens added to leaded gasoline. Sulfur levels can be controlled at the refinery.

The situation with regards to the effect of catalytic converters on the emission of sulfur oxides is not well defined. There is a concern that a significant amount of sulfur dioxide may be oxidized to sulfur trioxide in catalytic converters. This might have the effect of increasing the sulfuric acid aerosols in certain localized areas. Some ultra-conservative calculations indicate that these emissions could contribute to health problems.

As of this moment, the portion of sulfur dioxide that may be oxidized to sulfur trioxide in catalytic converters is in question. Several government and industrial laboratories have reported various levels of sulfur dioxide oxidation in passing through catalytic converters. There is a wide variance in these reported data. This is probably due to an undetermined combination of these factors: uncertainties in the sulfur oxide analytical techniques; the, as yet, uncharted effect of the many engine/catalyst operating variables; and the extent of sulfur storage in the converter. UOP believes further research is needed to define the extent of the problem and to seek acceptable solutions, if necessary.

Platinum Emissions

Some of the highest platinum losses we have observed in our potentially commercial catalyst were 0.2 grams and 0.17 grams over a 50,000 mile test. This is about a 7% loss of the original total platinum content. The most likely form of platinum loss is the zero-valent metal dust which is considered nontoxic. In order to be ultra-conservative, we have based our calculations on the hypothesis that all of the loss would be in the form of toxic platinum salts.

The test vehicles had an average gas mileage of 10 miles per gallon, an average air-fuel ratio of about 14 and a fuel density of six pounds per gallon. This results in an exhaust flow of 6.5 cubic meters per mile. Therefore, the "platinum salt" loss would amount to 0.0006 mg per cubic meter at the tail pipe, which is about one-third of the threshold limit value for the basic salts (but is one twenty-five thousandth of the threshold limit value for inert metal).[1] Note, this is the concentration in the exhaust itself before any dilution with ambient air.

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[1] 1967 American Conference of Government/Industrial Hygienists

In order to gain a better perspective, let's look at "platinum pollution" in another way. The observed platinum loss figures out to be 0.004 mg per mile, but there are 200.00 mg per mile of toxic lead salts emitted from each vehicle using normally leaded gasoline. This a multiplying factor of 50,000.

Alumina Emissions

The largest weight loss of alumina which has been observed in the 50,000 mile durability tests has amounted to about 5% of the original loading of the converter. However, in most cases the weight loss is within 1% or less of the original loading. For the purpose of a conservative calculation, we will assume an average loss of 5% of the original loading over 50,000 miles. Such a loss would correspond to about 100 grams per 50,000 miles. This corresponds to about .3 mg of alumina per cubic meter of exhaust. The threshold limit value for alumina and other so-called "inert" or "nuisance" particulates is given as 15 mg per cubic meter.[1] The threshold limit value is thus about 50 times higher than the maximum expected alumina concentration in the exhaust. By way of comparison, alumina emission would be two mg per mile and the lead emission from this same vehicle would be about 5 mg per mile even when so-called lead-free gasoline is used, assuming the proposed maximum allowable lead content of 0.05 grams/gallon for such fuel, or about two and one-half times as much lead will be emitted as alumina.

[1]1967 American Conference of Government/Industrial Hygienists

TOMORROW

The advent of catalysts for the control of pollutants from automotive engines opens the door to exciting opportunities for the future. One of the most promising developments in this area lies in the field of the self-tuning engine. In this type of power plant a conventional reciprocating engine is used in which the air-fuel mixture is continuously and automatically adjusted by a control unit in response to a continuous monitoring of the exhaust gas composition. It is a fortunate fact that the air-fuel mixture that is nearly optimum for engine performance and economy also produces an exhaust gas from which CO, HC and NOx are most easily eliminated by catalysts. That is, a single catalyst bed will remove all three of these emissions simultaneously provided their concentrations in the exhaust are held constant by correct air-fuel ratio control.

This system eliminates the need for an air pump, exhaust gas recycle and other engine modifications for controlling emissions. Most importantly, the catalyst assumes the responsibility for emission control, leaving the engine designer free to adopt any feature that will promote performance or efficiency; for example, optimized spark timing. Self-tuning engines as described above are now in the demonstration stage. Testing results show that emission control, performance and fuel economy are excellent. Preliminary studies indicate this system will save the automobile owner enough in fuel and maintenance to more than offset its incremental cost.

SUMMARY

TODAY'S CATALYST TECHNOLOGY CAN REDUCE HYDROCARBON AND CARBON MONOXIDE EMISSIONS TO STATUTORY LEVELS, INCREASE GAS MILEAGE AND SAVE MONEY FOR THE MOTORIST.

INDIRECT BENEFITS

	PRE-CATALYST CARS 1973 AND 1974	CATALYST CARS
FUEL PENALTY BASED ON CAR WITH NO EMISSION CONTROLS - 1970 BASE	10%	3%
LEAD COMPOUND EMISSIONS	200 MG/MILE (LEADED GAS)	5 MG/MILE (LEAD-FREE GAS)
HALOGEN EMISSIONS	100 MG/MILE (LEADED GAS)	2 MG/MILE (LEAD-FREE GAS)
EXPECTED MAINTENANCE SAVINGS FROM USING LEAD-FREE GAS	LEAD-FREE GAS NOT NORMALLY USED	5¢ PER GALLON

DIRECT BENEFITS

	EMISSION REDUCTIONS		
	EXHAUST FROM ENGINE	EXHAUST AFTER CONVERTER	STANDARD*
TOTAL HYDROCARBON	1.2 G/MILE	0.3 G/MILE	0.41 G/MILE
REACTIVE HYDROCARBON	0.78 G/MILE	0.15 G/MILE	N/A
PNAH	0.1 PPM	0.005 PPM	N/A
CARBON MONOXIDE	16.0 G/MILE	2.2 G/MILE	3.4 G/MILE
NOx	3.0 G/MILE	2.7 G/MILE	2.0 G/MILE

* 1976 INTERIM STANDARD

29-272 O - 74 - 28

SULFUR EMISSIONS

RESEARCH ON SULFUR TRIOXIDE EMISSIONS SHOULD CONTINUE; HOWEVER, EVIDENCE TO DATE INDICATES THAT THERE IS NO PROBLEM. SHOULD UNEXPECTED PROBLEMS OCCUR THROUGH RESEARCH IN THE NEXT FEW YEARS, THE OBVIOUS SOLUTION IS TO REMOVE SULFUR FROM GASOLINE.

FUTURE POSSIBILITIES WITH CATALYSTS

THE SELF-TUNING ENGINE IN COMBINATION WITH A 3-COMPONENT CATALYST EMISSION CONTROL SYSTEM FOR POST 1976 VEHICLES OFFERS THREE IMPORTANT BENEFITS:

1. ENGINE PERFORMANCE AND ECONOMY BETTER THAN PRE-CONTROLLED VEHICLES;
2. EMISSION CONTROL TO 1977 STANDARDS; AND
3. PAYING FOR ITSELF THROUGH FUEL AND MAINTENANCE SAVINGS.

IT HAS BEEN CONCLUSIVELY PROVEN THAT OXIDATION CATALYSTS REMOVE, DIRECTLY OR INDIRECTLY, SEVEN KNOWN POLLUTANTS: HYDROCARBONS, CARBON MONOXIDE, OXIDES OF NITROGEN, REACTIVE HYDROCARBONS, POLYNUCLEAR AROMATIC HYDROCARBONS, LEAD COMPOUNDS AND HALOGEN ACIDS. IN ADDITION, THE USE OF CATALYSTS CAN HELP PROVIDE PARTIAL SOLUTION TO THE FUEL SHORTAGE. WE AT UOP BELIEVE THAT THESE BENEFITS FAR OUTWEIGH THE MORE RAPID OXIDATION OF SO_2 TO SO_3 WHICH OCCURS IN THE ATMOSPHERE ANYWAY. THEREFORE, THE INSTALLATION OF CATALYTIC CONVERTERS SHOULD PROCEED.

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Saving Maintenance Dollars with Lead-Free Gasoline

D. S. Gray and A. G. Azhari
American Oil Co.

SOCIETY OF AUTOMOTIVE ENGINEERS

Automotive Engineering Congress
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Saving Maintenance Dollars with Lead-Free Gasoline

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ALTHOUGH NOT WIDELY RECOGNIZED, the use of lead-free gasoline saves money for motorists by reducing the need for frequent replacements of spark plugs, mufflers, and other automobile hardware exposed to gasoline and its combustion products. Maintenance cost savings have been reported informally for years by individual users of a lead-free premium gasoline marketed in the East and South, but only recently have reliable data been gathered to quantify the extent and significance of such savings.

Since 1966 we have been conducting large-scale studies to determine the difference in maintenance costs for cars operated on lead-free as opposed to leaded premium gasolines. Over 160 pairs of cars, matched closely in all mechanical and operating variables except type of gasoline, have been monitored for type and frequency of maintenance requirements as a function of mileage and age of car. The studies include fleet tests carried out by an independent research organization, as well as data collected from a marketing research panel chosen to represent a cross section of the average motoring public. Our results to date show that users of lead-free gasoline realize a clear-cut cost advantage that can amount to as much as \$0.05/gal over the lifetime of the average car.

We have also started to collect similar mileage and maintenance data for cars using the low-octane, lead-free, and low-lead gasolines that were first introduced in 1970. Although limited, these data also reveal a maintenance advantage for the users of lead-free fuels.

SOURCES OF DATA

Our principal sources of data were the closely controlled fleet tests, which involved a total of 24 cars, and the panel survey, which involved 302 cars—a sufficiently large number to permit statistical analysis of observed differences. By contrast, our completed work on low-lead gasolines involves only five cars.

FLEET TESTS - The fleet comprised four cars each of the new 1967 and 1968 models of three different makes that had engine displacements of 396, 390, and 383 in^3, respectively. All cars of the same make and model were equipped with identical engines and accessories, and were produced in close succession to minimize the possibility of manufacturing variations. All were inspected when received, and such operating variables as ignition timing and carburetor float level were adjusted where necessary to standardize engine operation.

This fleet was operated by an independent contract research organization whose employees used the cars for commuting and company business in city and suburban driving in the Chicago area. Within each set of four identical cars, two were fueled exclusively with the commercially available lead-free premium gasoline, while the other two were fueled with various commercial leaded premium gasolines. The fuels were delivered to the organization identified solely by color code; no information concerning the composition of the contents was provided.

ABSTRACT

Motorists who use lead-free rather than leaded gasolines postpone the need to replace spark plugs, exhaust systems, and carburetors, and thus save a significant part of their maintenance dollar. These savings were documented in a four-year test with a fleet of automobiles operated in city-suburban driving, and in a five-year survey of a representative sample of the motoring public. Savings on gasoline-related maintenance over the lifetime of an average car were about \$0.05/gal in the fleet tests and \$0.04/gal in the survey.

Car assignments among the employees were rotated daily to ensure that all cars were treated similarly over the long run. Each car averaged about 7500 miles/year, and prescribed warranty procedures for oil and filter changes were always observed. When fuel-related maintenance work was required, the contractor attempted to simulate the average car owner in that service was performed only upon clearly detectable evidence that it was really needed. If the trouble was in a test-related part, that is, one that was in contact with the gasoline before or after combustion, the specific repairs were made by an authorized service garage for the car make involved. All invoices for such maintenance work were retained and analyzed by the contractor, and monthly reports were submitted to summarize the test results.

PANEL SURVEY - Motorists for the panel survey were selected by a nationally known marketing research firm that maintains a nationwide panel of over 90,000 families who are used mainly to test and evaluate new products. First, the firm sent qualifying questionnaires to the 40,000 panel members who live in the states where lead-free premium gasoline is sold, asking whether they kept complete records on their cars and would make this information available. The replies

Fig. 1 - Location of participants in panel survey

showed that many of the panel members kept such records, and that users of lead-free and leaded gasolines could be paired from this population in terms of car year, make and model, geographical area, and mileage driven per year.

As summarized in Table 1, 302 panelists (151 pairs) were selected. Fig. 1 shows their geographical distribution. All of them were supplied with diaries which they were asked to mail back each month. As illustrated in Fig. 2, the diary entries covered car identification and operating data, gasoline and oil purchases, and all maintenance, whether gasoline-related or not. All invoices for maintenance work were returned with the monthly diaries. Throughout the survey, the marketing research firm made all contacts with the panelists, none of whom was told the purpose of the diaries.

Table 1 - Distribution of Cars in Panel Survey

Manufacturer	Number of Cars by Model Year					
	1969	1968	1967	1966	1965*	Total
General Motors Corp.	16	70	22	14	12	134
Ford Motor Co.	14	38	14	6	6	78
Chrysler Corp.	6	12	12	2	8	40
American Motors Corp.	4	2	2	2	-	10
German firms	4	4	4	-	2	14
Other foreign firms	4	18	4	-	-	26
Total cars	48	144	58	24	28	302

*Includes four 1964 and four 1963 cars.

EVALUATION OF LOW-LEAD GASOLINES - During the winter of 1970-71, five identical cars having 350 in^3 engines were given to our own employees for commuter driving, ranging from 8-40 miles/trip, and were rotated daily among drivers to ensure uniform treatment. Fuels for the test included a conventional leaded regular gasoline, a low-lead regular, a lead-free regular, a lead-free premium, and a lead-free regular to which a lead antiknock compound free of halogen scavengers was added at a level to match the low-lead regular. The muffler of each car was fitted with a Corrosometer Probe (Magna Corp., Santa Fe Springs, Calif.) near the exhaust pipe outlet, and readings were taken daily to determine corrosion rates.

RESULTS AND DISCUSSION

Results from the fleet tests and panel survey were analyzed for the type, frequency, and costs of gasoline-related maintenance, including exhaust system replacements (mufflers and/or exhaust pipes), spark plug replacements, and servicing of carburetors. Then these data were converted to the common basis of cost of maintenance/gal of fuel as affected by type of fuel, age of car, and total accumulated mileage. This approach was taken to eliminate any distortions arising from the varying number of cars and mileages.

Data from the low-lead study were limited to the extent of muffler corrosion as affected by type of fuel.

TYPE AND FREQUENCY OF MAINTENANCE - Differences between cars operated on lead-free and leaded gasolines

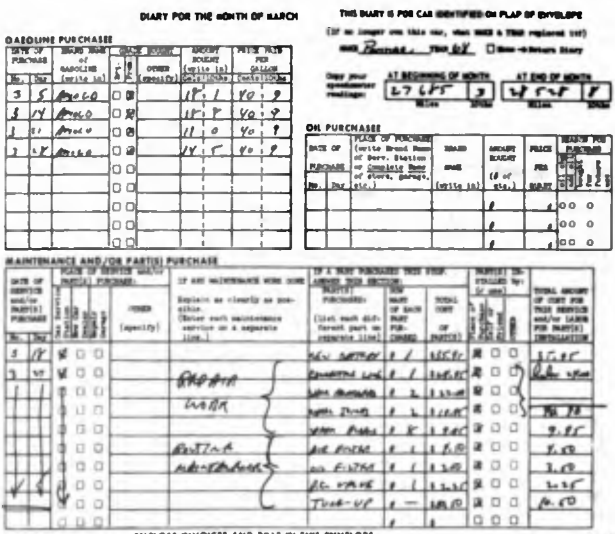

Fig. 2 - Sample diary, panel survey

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in terms of exhaust hardware and spark plug replacements are shown in Table 2 for the fleet tests, and Table 3 for the panel survey. Overall, such replacements with leaded gasolines were more than double those with lead-free.

In the panel survey, the difference between gasolines is especially apparent for exhaust hardware replacements but less so for spark plugs. Evidently, to forestall future problems, the average motorist is inclined to replace spark plugs by mileage rather than need. This practice may minimize the differences noted between gasolines by the general public. It is particularly noteworthy that none of the 1965 or 1966 cars with lead-free gasolines required exhaust system repairs during the survey.

COMPARATIVE COSTS OF GASOLINE-RELATED MAINTENANCE - The distribution of gasoline-related maintenance costs for cars in the fleet tests and the panel survey are shown in Tables 4 and 5, respectively. In only three cases, as indicated by the underlined numbers in Table 4, were the costs with lead-free gasolines higher than or equal to those encountered with leaded gasolines.

Because of the technique used to obtain data from motorists in the panel survey, it was not always possible to separate the costs of spark plug replacements from those of other ignition services such as points and condensers. Consequently, all ignition maintenance is included under a common heading in Table 5. The "other" category refers mainly to maintenance work on hydraulic valve lifters.

In all car year groups, the motorists who used the lead-free gasoline spent much less money for exhaust system and ignition servicing than the motorists who used leaded gasoline. The lead-free gasoline also showed a cost advantage regarding carburetor servicing in the older cars. In the category of other engine expenses, the advantage for lead-free gasoline was small or nonexistent, except for the 1965 group where a large advantage for lead-free gasoline was observed. This category of other engine work is important in another respect, however. If there is validity to the claims sometimes made that use of lead-free gasoline results in adverse side effects such as valve seat wear, such expenses should have been encountered for the older lead-free gasoline cars. That such expenses were not encountered reflects the experience of cars operated by motorists in the real world, as opposed to the results sometimes obtained from accelerated tests.

An important point is how the overall savings with lead-free gasolines increase with the age of the car. The 1965 or older models in the panel survey (Table 5) realized a net savings of \$0.04/gal. This point is further emphasized when the data for the fleet tests are analyzed as a function of time, as summarized in Table 6. In a 48-month period, the 1967 cars showed cumulative savings of \$0.056/gal. The 1968 cars, which are still on test, show a similar trend.

In both the fleet test and the panel survey, gasoline-related maintenance costs were relatively low during the first two years. Although the use of lead-free gasoline generally was associated with savings during this period, the amount of these savings was not large. Following the second year, however, the maintenance costs for the cars using lead-free gasoline rose only modestly, whereas the maintenance costs for the leaded gasoline cars rose significantly.

The significance of the observed differences in maintenance costs is illustrated in Table 7, which summarizes the statistical analysis ("t" test and analysis of variance) of the data from the panel survey.

MUFFLER CORROSION WITH VARIOUS GASOLINES - The results of our muffler corrosion tests are shown in Table 8. Compared with the lead-free gasolines, both the conventionally leaded and the low-lead regular gasolines caused about ten times as much muffler corrosion. Consequently, it appears that a motorist would not receive maintenance cost benefits from low-lead gasoline in direct proportion to the reduction in lead content. However, the fact that the leaded gasoline made without halogen scavengers caused only slightly more corrosion than the lead-free gasolines indicates that acidic products formed by the scavengers are mainly responsible for corroding mufflers and other exhaust system hardware.

Table 3 - Exhaust Hardware and Spark Plug Replacements Required in Panel Survey

No. of Matched Pairs	Model Year	Total Number of Replacements: Exhaust, Leaded	Exhaust, Lead-Free	Spark Plug Sets, Leaded	Spark Plug Sets, Lead-Free
24	1969	1	0	6	8
72	1968	8	0	50	40
29	1967	3	2	22	19
12	1966	5	0	9	5
14	1965	7	0	19	8

Table 2 - Exhaust Hardware and Spark Plug Replacements Required in Fleet Tests

Car Model Year	Test Duration, Mo.	Total Number of Cars: Leaded	Total Number of Cars: Lead-Free	Total Number of Replacements: Exhaust, Leaded	Exhaust, Lead-Free	Spark Plug Sets, Leaded	Spark Plug Sets, Lead-Free
1967	48	5*	6	16	7	11	6
1968	44	6	6	21	1	12	6

*One car was destroyed in an accident.

Table 4 - Distribution of Maintenance Costs in Fleet Tests

Model Year	Make	Maintenance Costs, Cents/Gal: Exhaust, Leaded	Exhaust, Lead-Free	Spark Plugs, Leaded	Spark Plugs, Lead-Free	Carburetor, Leaded	Carburetor, Lead-Free
1967	A	4.2	2.0	2.2	0.3	2.4	1.4
	B	7.3	2.8	0.6	1.3	0.6	0.6
	C	6.3	1.4	1.8	0.5	2.0	0.6
1968	A	3.6	1.1	1.9	0.6	1.0	1.9
	B	4.8	0.0	1.8	0.7	2.6	0.1
	C	5.3	0.0	1.6	1.1	0.3	0.0

Table 5 - Distribution of Maintenance Costs in Panel Survey

Model Year	Maintenance Costs, Cents/Gal: Exhaust, Leaded	Exhaust, Lead-Free	Ignition, Leaded	Ignition, Lead-Free	Carburetor, Leaded	Carburetor, Lead-Free	Other, Leaded	Other, Lead-Free	Total, Leaded	Total, Lead-Free
1969	0.1	0.0	1.6	1.0	0.1	0.1	0.1	0.0	1.9	1.1
1968	0.5	0.0	1.9	1.5	0.2	0.2	0.1	0.0	2.7	1.7
1967	0.6	0.2	2.5	2.2	0.8	0.3	0.1	0.1	4.0	2.8
1966	1.7	0.0	2.8	1.9	0.3	0.2	0.0	0.0	4.8	2.1
1965	1.7	0.1	3.4	2.1	0.9	0.4	0.9	0.3	6.9	2.9

Table 6 - Cumulative Saving with Time in Fleet Tests

Model Year	Duration of Test, Mo.	Maintenance Costs, Cents/Gal: Leaded Gasoline	Lead-Free Gasoline	Difference, Leaded–Lead-Free
1967	12	0.0	0.0	0.0
	24	2.3	0.6	1.7
	36	5.7	1.5	4.2
	48	9.3	3.7	5.6
1968	12	0.7	0.2	0.5
	24	1.2	1.2	0.0
	36	5.8	1.9	3.9
	44	7.0	1.9	5.1

Table 7 - Statistical Analysis of Observed Differences in Maintenance Cost Data for the Panel Survey

Model Year	No. of Pairs	Observed Cost Difference (Leaded–Lead-Free), Cents/Mile	Significance Level*
1969	24	0.053	0.70
1968	72	0.066	0.95
1967	29	0.094	0.70
1966	12	0.188	0.95
1965	14	0.280	0.99
All	151	0.099	0.999

*95% confidence interval: 0.046–0.153 ¢/mile.

CONCLUSION

Lead-free gasolines typically cost slightly more than leaded gasolines, and a frequently raised question concerns why a customer should pay this higher price. Our work has shown that the steady use of lead-free gasoline ensures significant savings in maintenance costs. Eliminating the lead antiknock compounds from the gasoline unquestionably reduces or postpones the need for exhaust system repairs, spark plug replacements, carburetor servicing, and other gasoline-related maintenance. Moreover, no adverse side effects such as valve seat wear have been observed.

Table 8 - Corrosion Rates in Muffler Test with Various Gasolines

Type of Gasoline	Corrosion Rate, mils/1000 miles
Conventionally leaded	0.16
Low-lead	0.18
Lead-free regular	0.015
Lead-free premium	0.010
Leaded without scavenger	0.018

50,000 MILE STANDARD DURABILITY TESTS AND ABUSE DURABILITY TESTS USING 260 CU. IN. REACTORS AND PELLETED CATALYST

Automotive Products Division
Universal Oil Products Company
2454 Dempster Street
Des Plaines, Illinois 60016 312-391-2000
UOP

50,000 Mile Standard Durability Tests on Catalysts PZ-236 & PZ-217
50,000 Mile Abuse Durability Tests on Catalysts PZ-217-1 & PZ-255-2

Summary:

Pelleted catalysts PZ-236 and PZ-217, which were tested for 50,000 miles under standard durability conditions, met the 1975 Federal Standards for hydrocarbon and carbon monoxide emissions.

Pelleted catalysts PZ-217-1 and PZ-255-2, which were tested for 50,000 miles under abuse durability conditions also met the 1975 Federal Standards for hydrocarbon and carbon monoxide emissions. The abuse testing included periods of misfire, contamination of fuel with tetra-ethyl-lead and addition of oil to the fuel to simulate engine oil consumption.

Discussion - Standard Durability Tests

In order to carry out a meaningful catalyst development program, it is imperative to observe the performance of the catalyst per se, separate and distinct from the normal variability of emissions from an ageing engine.

To accomplish this end the converter was removed from the ageing vehicle at periodic intervals (~4,000 miles) and installed on a standard vehicle which was operated and maintained so as to keep base engine emissions reasonably constant. This vehicle was a standard dealer supplied unit with no changes made to it and kept tuned to factory specifications.

Ageing was done about equally on a road course and on chassis dynamometers. Figure 1 shows the procedures used.

The vehicles were operated using Indolene Clear test fuel (refer Figure 2 for fuel analysis). The crankcase lubricant was Super Shell 10W-20W-40.

Results:

PZ-236 is a pelleted oxidation catalyst with a total noble metal loading of 18/1000 troy ounces (0.56 grams per vehicle). The catalyst was aged in a 260 in^3 converter on a 1971, 350 CID Ford without AIR (Air Injection Reactor) for 50,000 miles.

The 1975 emissions are plotted against total catalyst mileage in Figure 3 for hydrocarbon and Figure 4 for carbon monoxide. A sum of the least squares line has been fitted through the data points.

PZ-217 is also a pelleted noble metal catalyst with a loading of 72/1000 troy ounces (2.24 grams per vehicle). The catalyst was aged in a 260 in^3 converter on a 1971, 351 CID Ford and a 1972 Chevrolet, 350 CID. The converter was 260 in^3 in bed volume.

Results (Continued)

Graphs illustrating hydrocarbon and carbon monoxide emissions versus mileage are included in the appendix as Figura 6 snd Figure 7 respectively. Agsin, a least squares fit line has been drawn through the data.

Discuasion - Abuse Dursbility Testa

In this test "abuse" durability conditions were used in order to appraise and compare catalyst performance when it ia subjected to abusive use. The effects on performance of lesd and other additive poisoning, misfiring and simulated oil consumption were investigated.

Lead contamination wss impoaed by operating on fuel containing 2.5 grams lead per gallon. At about 30,000 milea oil was added to the fuel to simulate a consumption of 1 quart per 1,000 miles. This was continued through 50,000 miles. The oil that was used waa Shell X-100 Multigrade 10W-20W-30; it was selected entirely on the basis of ssles popularity. The oil analysia is shown in Figure 5.

The catalyst was periodically caused to misfire by disconnecting 1 or 2 apark plugs. Figure 8 summarizes these conditiona including the total time of misfiring and temperatures experienced.

The catalyst waa sged under theae severe conditions for 50,000 miles using a 1973 Chevrolet, 350 CID, equipped with AIR and EGR (Exhaust Gas Recirculation). Approximately 50% of tha sgeing waa done on a chassis dynamometer with the remainder being done on the road (normal milesge accumulation procedures were used).

The test fuela used are included in the legend on the durability plots.

Results:

PZ-217-1 is the sama as the previously mentioned PZ-217 which was run under standard durability conditions. The hydrocarbon and carbon monoxide emiaaion plots are shown as Figure 9 and Figure 10 respectively.

PZ-255-2 ia alao a pelleted catalyst with a loading of approximately 50/1000 troy ounces (1.56 grams per vehicle) total metals. The abusa dursbility procedure was used.

The ageing car was a 1973 Chevrolet. Misfire summsry data are shown in Figure 11. Figure 12 snd Figure 13 show the emission data for the 50,000 mile teat.

The emisaion results for PZ-217 are far below the Federal Standards after ageing for 50,000 milea.

A summary is included, Figure 14, which lists the weighta of the catalysts at 0 miles and 50,000 miles.

Conclusions:

These tests have firmly demonstrated that catalysts are not as fragile as often thought. It was shown conclusively that high temperature and poisons, which are the parameters which most often affect catalysts, do not destroy a catalyst. By comparing standard durability tests with the abuse durability tests it is concluded that catalysts exposed to hostile conditions are not degraded enough to affect their final performance over 50,000 miles using the U.S. Federal Standards as the criteria.

Figure 1

AGEING SCHEDULES

Road Ageing Lap

Total Average Miles Per Lap	48 Miles
Total Average Time Per Lap	1.33 Hours
Average Speed Per Lap	36 MPH
Maximum Speed	~75 MPH

13-Mode Dynamometer Ageing Cycle

Mode	Mode Time	Total Time
Idle	15 Sec.	15 Sec.
I - 37.5 MPH	14 Sec.	29 Sec.
37.5 MPH Cruise	13 Sec.	42 Sec.
37.5 MPH - 18.75 MPH	11 Sec.	53 Sec.
18.75 MPH - 50 MPH	21 Sec.	74 Sec.
50 MPH Cruise	44 Sec.	118 Sec.
50 MPH - 25 MPH	17 Sec.	135 Sec.
25 MPH Cruise	10 Sec.	145 Sec.
25 MPH - I	8 Sec.	153 Sec.
Idle	10 Sec.	163 Sec.
I - 62.5 MPH	17 Sec.	180 Sec.
62.5 MPH Cruise	40 Sec.	220 Sec.
62.5 MPH - I	20 Sec.	240 Sec.

Figure 2

TYPICAL FUEL INSPECTION

Clear Indolene	
RVP, psi	8.5
Gravity, °API @ 60°F	58.5
Distillation, °F	
IBP	95
5%	120
10	135
30	193
50	225
70	250
90	330
95	362
EP	408
% Rec.	98.0
Botts.	1.0
Loss	1.0
Sulfur, Wt.%	0.014
ASTM gum, mg/100ml	1
Induction Period, min.	>1200
Peroxide No.	0.2
F.I.A. on C_6+, Vol.%	
Aromatics	38.2
Olefins	3.5
P + N	58.3
Res. Oct. No.	97.2
Motor Oct. No.	88.2
Pb, gr/gal	0.011
P, gr/gal	<0.005

Figure 3

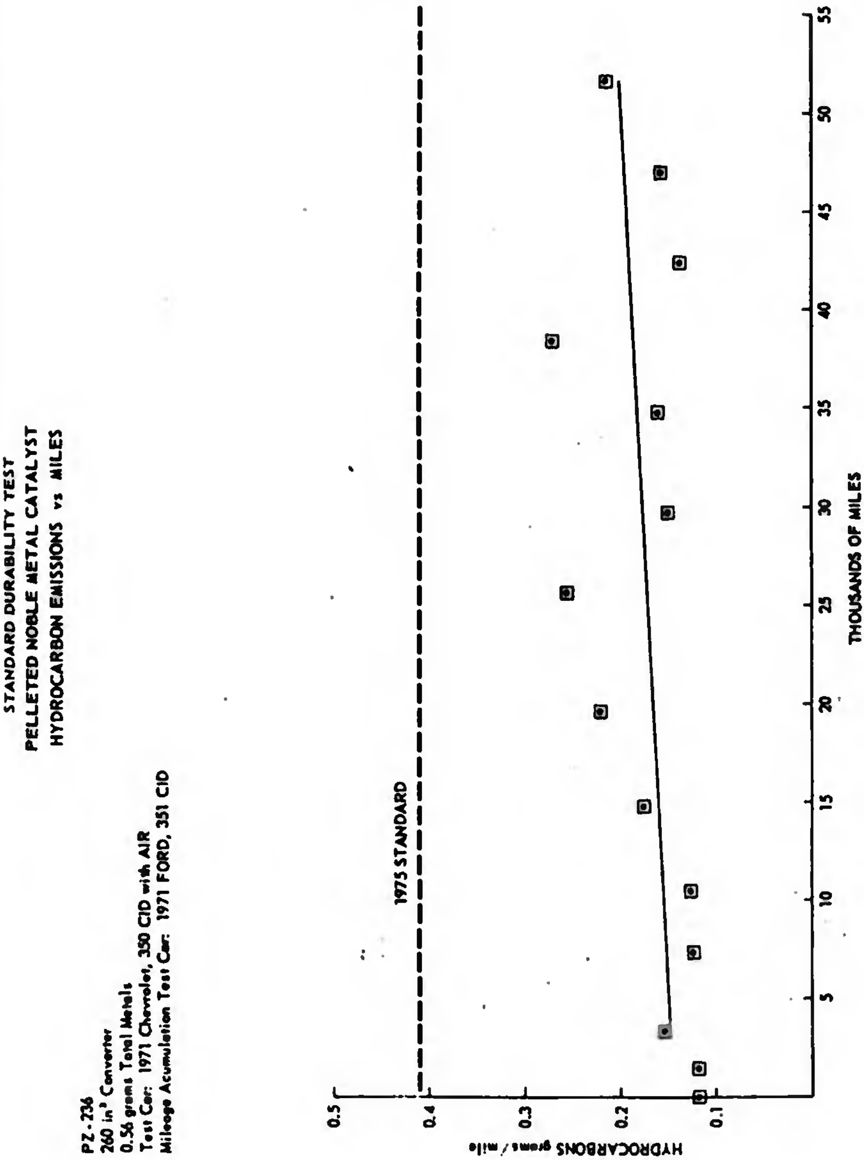

STANDARD DURABILITY TEST
PELLETED NOBLE METAL CATALYST
HYDROCARBON EMISSIONS vs MILES
PZ-236
260 in³ Converter
0.56 grams Total Metals
Test Car: 1971 Chevrolet, 350 CID with AIR
Mileage Acumulation Test Car: 1971 FORD, 351 CID
1975 STANDARD
HYDROCARBONS grams/mile
0.5
0.4
0.3
0.2
0.1
THOUSANDS OF MILES
5
10
15
20
25
30
35
40
45
50
55

Figure 4

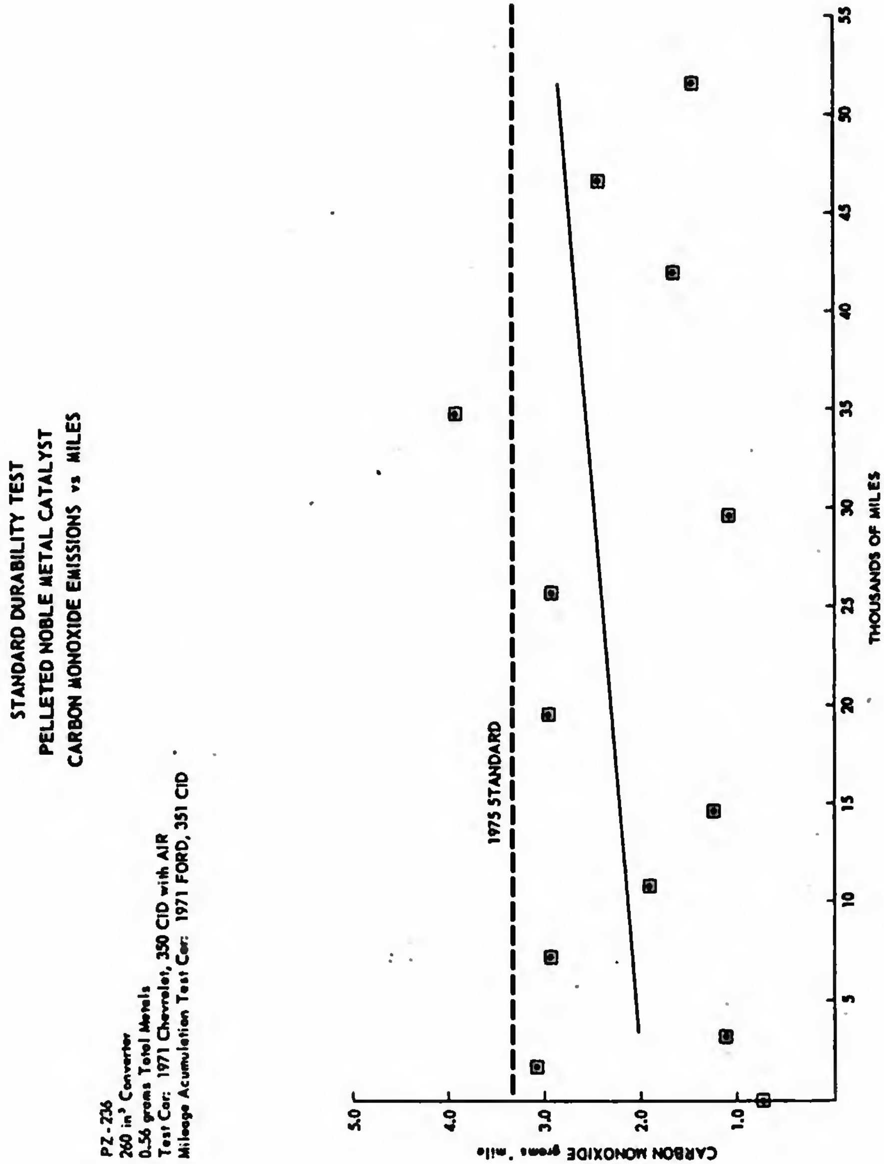

STANDARD DURABILITY TEST
PELLETED NOBLE METAL CATALYST
CARBON MONOXIDE EMISSIONS vs MILES
PZ-236
260 in³ Converter
0.56 grams Total Metals
Test Car: 1971 Chevrolet, 350 CID with AIR
Mileage Acumulation Test Car: 1971 FORD, 351 CID
1975 STANDARD
CARBON MONOXIDE grams/mile
5.0
4.0
3.0
2.0
1.0
5
10
15
20
25
30
35
40
45
50
55
THOUSANDS OF MILES

Figure 5

TYPICAL OIL ANALYSES

Lubricant	Zn Wt.ppm	Ca Wt.ppm	Ba Wt.ppm	P %	Si Wt.ppm	N %	S %	Pb Wt.ppm
Shell X-100 SAE 30	1400	3650	<0.5	0.13	<4	0.076	0.38	<4
Super Shell 10W-20W-40	1500	2300	<0.5	0.17	<10	0.030	0.43	<3

Figure 6

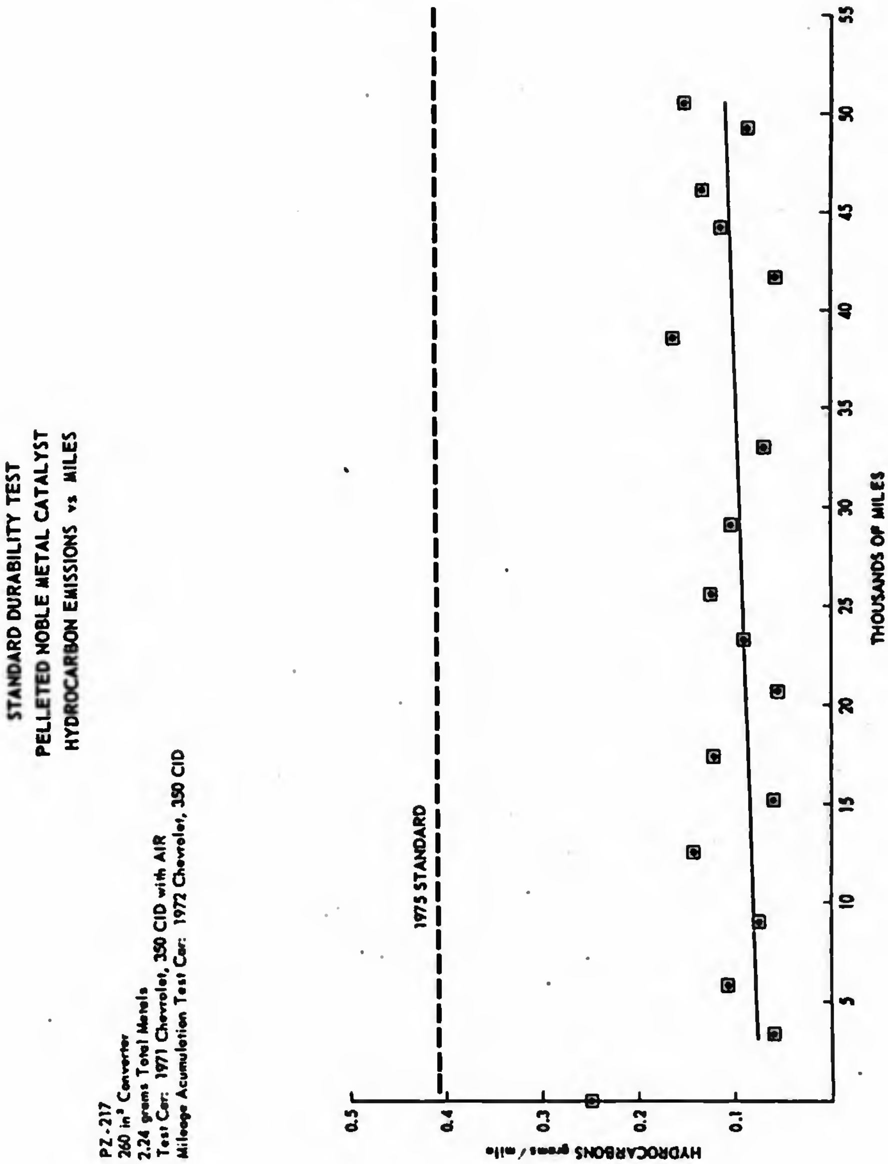

STANDARD DURABILITY TEST
PELLETED NOBLE METAL CATALYST
HYDROCARBON EMISSIONS vs MILES
PZ-217
260 in³ Converter
2.24 grams Total Metals
Test Car: 1971 Chevrolet, 350 CID with AIR
Mileage Acumulation Test Car: 1972 Chevrolet, 350 CID
1975 STANDARD
HYDROCARBONS grams/mile
0.5
0.4
0.3
0.2
0.1
5
10
15
20
25
30
35
40
45
50
55
THOUSANDS OF MILES

Figure 7

STANDARD DURABILITY TEST
PELLETED NOBLE METAL CATALYST
CARBON MONOXIDE EMISSIONS vs MILES

PZ-217
260 in³ Converter
2.24 grams Total Metals
Test Car: 1971 Chevrolet, 350 CID with AIR
Mileage Accumulation Test Car: 1972 Chevrolet, 350 CID

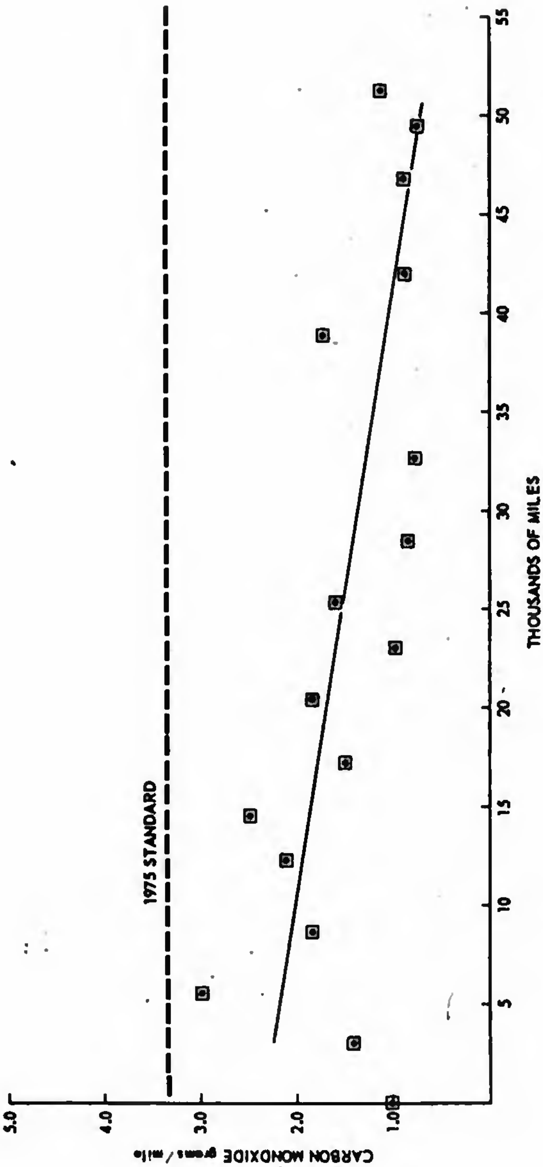
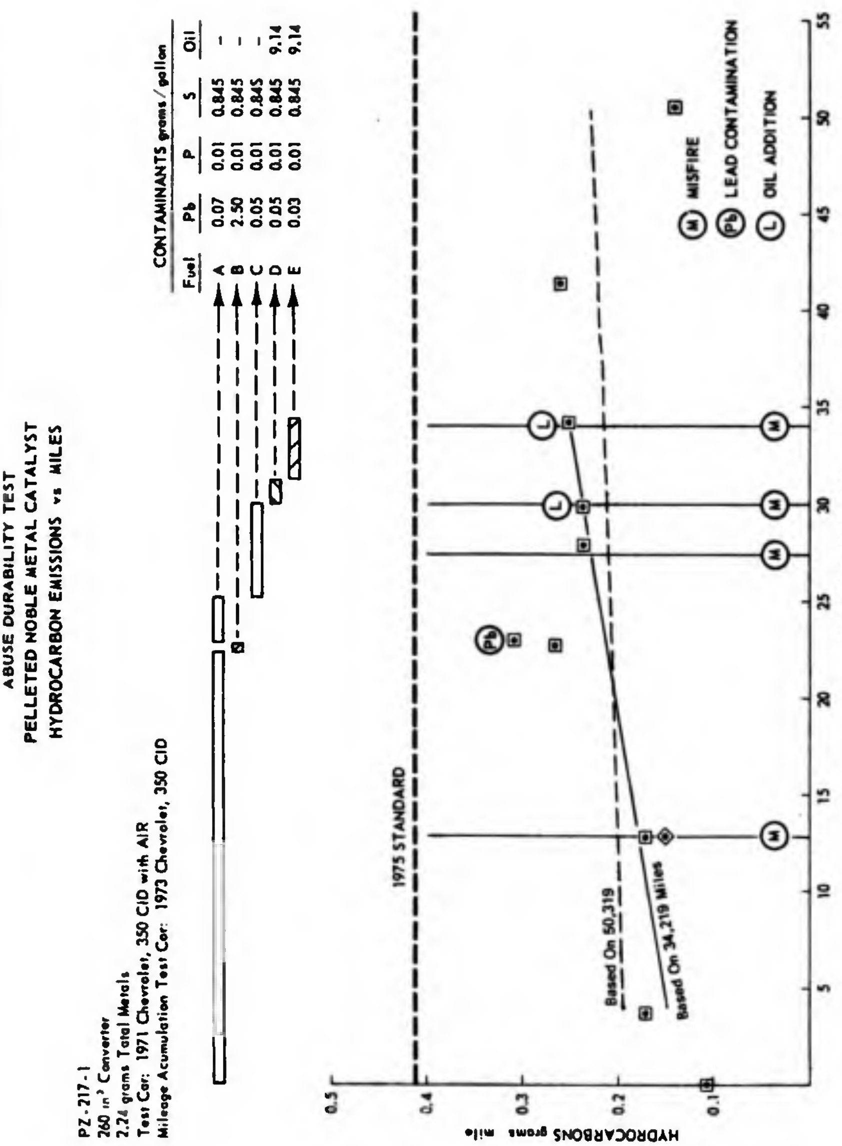


Figure 8

PZ-217-1
CCD-1272-19
Misfire Summary
Bed Temperature Data

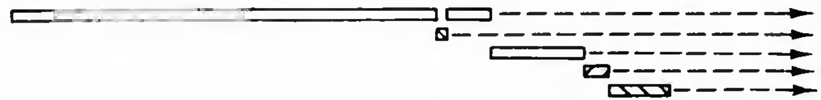
PZ-217-1 Misfire Summary

Mileage	Time	Distance	Temperature Average	Temperature Maximum	# of Plugs Disconnected
13,000	1371 Sec.		1500°F	1587°F	2
27,819	31 Min.		1500°F	1800°F	2
30,048	40 Min.		1400°F	1550°F	1
34,219		268 MI.	1250°F	1600°F	1
50,319	90 Min.		1450°F	1680°F	1


ABUSE DURABILITY TEST
PELLETED NOBLE METAL CATALYST
HYDROCARBON EMISSIONS vs MILES
PZ-217-1
260 in³ Converter
2.24 grams Total Metals
Test Car: 1971 Chevrolet, 350 CID with AIR
Mileage Acumulation Test Car: 1973 Chevrolet, 350 CID
CONTAMINANTS grams/gallon
Fuel Pb P S Oil
A 0.07 0.01 0.845 -
B 2.50 0.01 0.845 -
C 0.05 0.01 0.845 -
D 0.05 0.01 0.845 9.14
E 0.03 0.01 0.845 9.14
1975 STANDARD
Based On 50,319
Based On 34,219 Miles
M MISFIRE
Pb LEAD CONTAMINATION
L OIL ADDITION
HYDROCARBONS grams mile
THOUSANDS OF MILES

ABUSE DURABILITY TEST
PELLETED NOBLE METAL CATALYST
CARBON MONOXIDE EMISSIONS vs MILES

PZ-217-1
260 in³ Converter
2.24 grams Total Metals
Test Car: 1971 Chevrolet, 350 CID with AIR
Mileage Acumulation Test Car: 1973 Chevrolet, 350 CID



CONTAMINANTS grams / gallon

Fuel	Pb	P	S	Oil
A	0.07	0.01	0.845	-
B	2.50	0.01	0.845	-
C	0.05	0.01	0.845	-
D	0.05	0.01	0.845	9.14
E	0.03	0.01	0.845	9.14

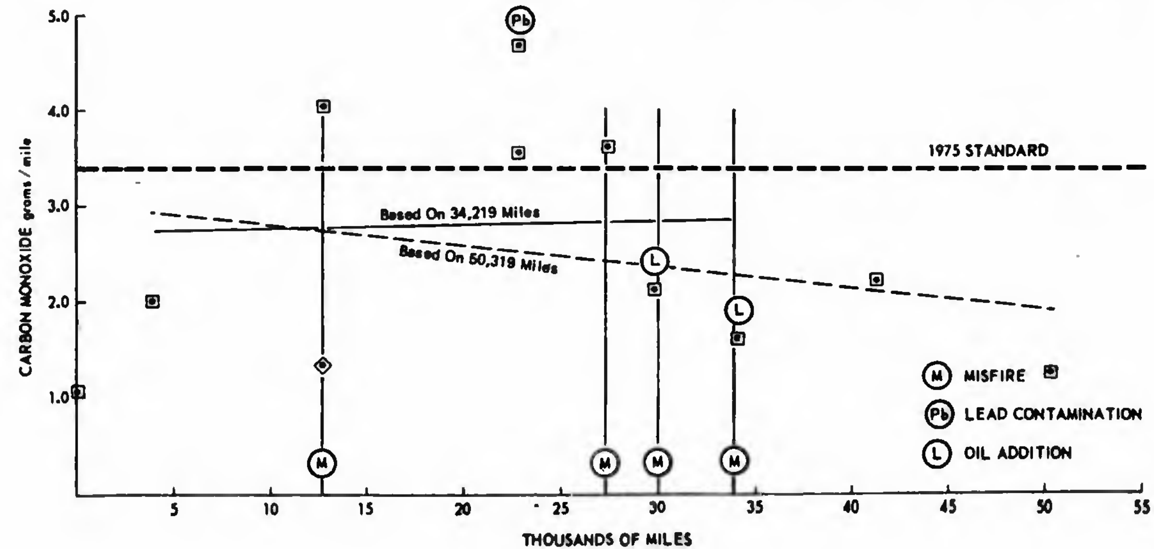


Figure 11

PZ-255-2
CCD-1272-18
Misfire Summary
Bed Temperature Data

PZ-255-2 Misfire Summary

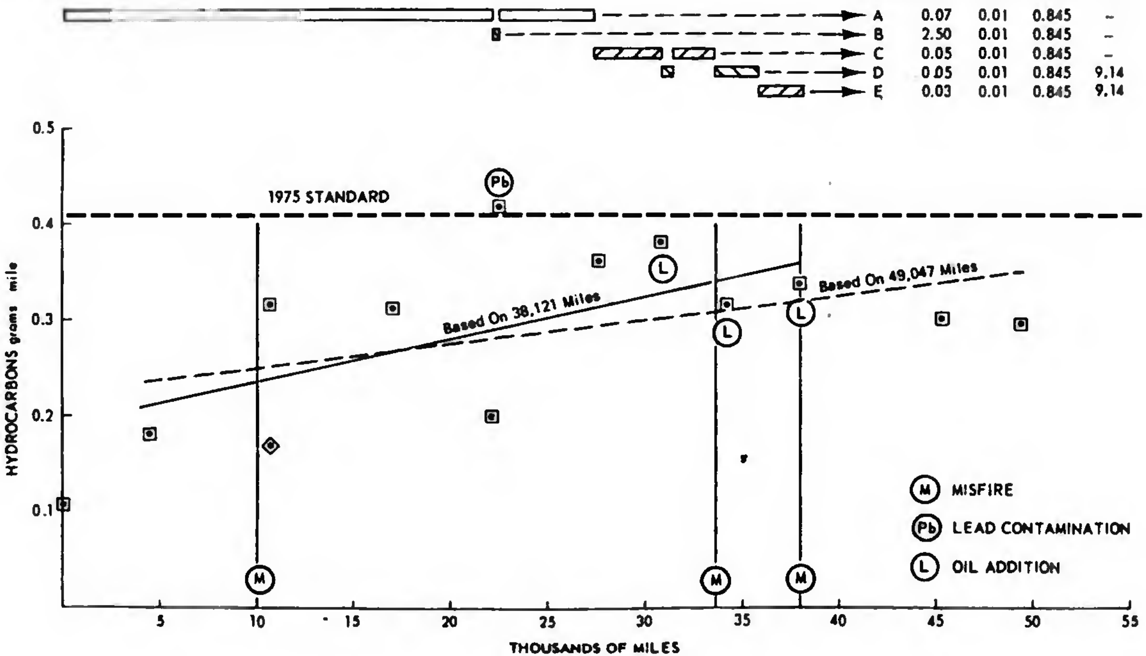
Mileage	Time	Distance	Temperature Average	Temperature Maximum	# of Plugs Disconnected
10,000	1371 Sec.		1280°F	1370°F	1
33,801	37 Min.		1350°F	1430°F	1
38,121		252 Mi.	1300°F	1700°F	1
49,047	90 Min.		1430°F	1480°F	1

ABUSE DURABILITY TEST
PELLETED NOBLE METAL CATALYST
HYDROCARBON EMISSIONS vs MILES

PZ-255-2
260 in³ Converter
1.56 grams Total Metals
Test Car: 1971 Chevrolet, 350 CID with AIR
Mileage Acumulation Test Car: 1973 Chevrolet, 350 CID

CONTAMINANTS grams / gallon

Fuel	Pb	P	S	Oil
A	0.07	0.01	0.845	–
B	2.50	0.01	0.845	–
C	0.05	0.01	0.845	–
D	0.05	0.01	0.845	9.14
E	0.03	0.01	0.845	9.14



ABUSE DURABILITY TEST
PELLETED NOBLE METAL CATALYST
CARBON MONOXIDE EMISSIONS vs MILES

P2-255-2
260 in³ Converter
1.56 grams Total Metals
Test Car: 1971 Chevrolet, 350 CID with AIR
Mileage Acumulation Test Car: 1973 Chevrolet, 350 CID

CONTAMINANTS grams / gallon

Fuel	Pb	P	S	Oil
A	0.07	0.01	0.845	–
B	2.50	0.01	0.845	–
C	0.05	0.01	0.845	–
D	0.05	0.01	0.845	9.14
E	0.03	0.01	0.845	9.14

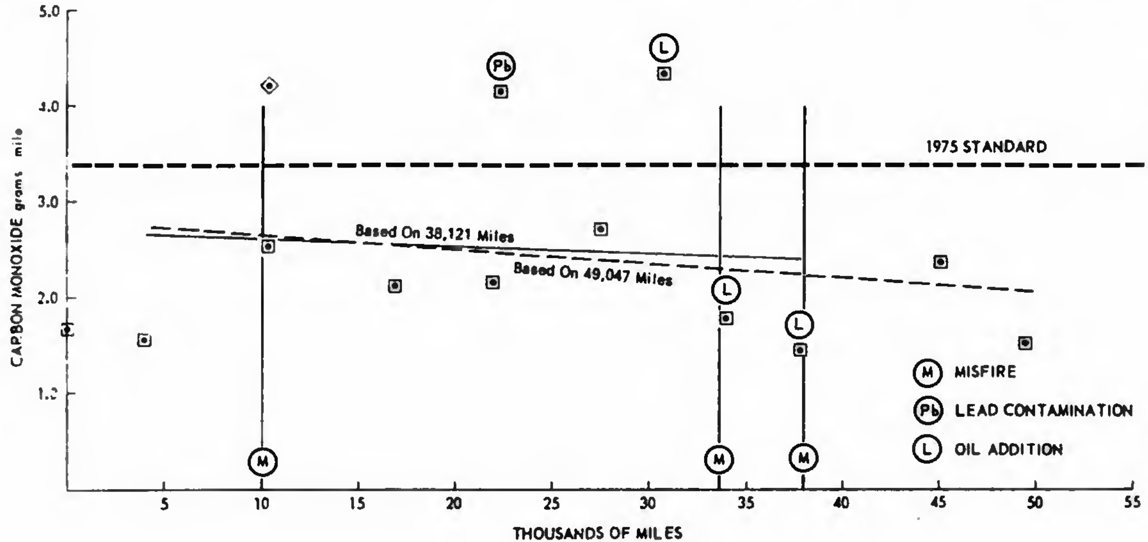


Figure 14

Catalyst Gravimetric Data

	Wt. In-grams	Wt. Out-grams	Remarks
PZ-236	1696	1862	Full & Tight
PZ-217	1822	1836	Full & Tight
PZ-217-1	1524	1572	Full & Tight
PZ-255-2	1624	1657	Full & Tight

Mr. ROGERS. Thank you very much, Mr. Dunham.

I think this points up that we need to make a decision and make it very quickly.

Mr. DUNHAM. Yes, sir.

Mr. ROGERS. Mr. Heinz.

Mr. HEINZ. Thank you, Mr. Chairman.

I would like to thank you, Mr. Dunham, and I would also like to thank you, Mr. Leventhal.

I note that in your testimony you both basically agree, with the exception of the treatment of NO_x. Mr. Leventhal, I believe you suggested for 1976 a 0.9, a 9, and a 2 with respect to NO_x?

Mr. LEVENTHAL. Yes, sir.

Mr. HEINZ. You, Mr. Dunham, suggested for 1976 a 0.9, a 9, and a 3 with respect to NO_x?

Mr. DUNHAM. Yes, sir.

Mr. HEINZ. Could either of you explain the difference in your recommendation for NO_x?

Mr. LEVENTHAL. Basically, I was silent on the NO_x one, because there is really very little difference between the 3 and the 2 in terms of fuel economy. However, if I had to choose and recommend a course of action, I would say, since the auto industry is all well along the way for 1975 California, for 0.9, 9, and 2 NO_x, I would think that would be the one to carry over.

Mr. HEINZ. Mr. Dunham, do you also agree that there would be little difference in fuel economy between a 0.9, 9, and 2, and a 0.9, 9, and 3?

Mr. DUNHAM. Yes, sir, I would. The reasons for my suggestion of the 3, it is the most difficult of the three to obtain, and I did hear some substantial expression of concern on the part of the automotives here today and previously that they could reliably meet 2 grams per mile NO_x consistently, under the testing methods that Mr. Cole was talking about.

Mr. LEVENTHAL. I would like to add one thing, Mr. Heinz, if I may. My recommendation was that the law not be changed but that if this committee felt it had to freeze for some reason, that I would say that if you froze, the place to do it is better at 0.9, 9, and 2, which would guarantee that the alleged reason that the freeze was required, to get the fuel economy, was, in fact, achieved, and not to find out it was done in such a way that it was counterproductive to your objective.

Mr. HEINZ. I am glad you pointed out that. I had not forgotten. I was just trying to compare for the record.

Mr. ROGERS. Dr. Haensel?

Mr. HAENSEL. Mr. Heinz, I think the reason for our 3 suggestion on the NO_x is really that we are hopeful that over a period of time we may return to somewhat higher compression ratios, as we are able to make more and more unleaded gasoline at the higher octane level, which, in turn, will give us a much higher efficiency of combustion. And as a result, I think energywise, we will be better off. And so we are merely trading one for the other one, but at the same time we realize that we are trying to accomplish both purposes at the same time.

Mr. HEINZ. Let me ask either of you gentlemen one further question, if I may.

If you take the existing 1976 standard, the 0.41 and the 3.4 and the 2.0 for the Federal 49 versus the California interim standard, 0.99 to 2.0, what kind of a fuel penalty do you envisage between meeting those two sets of standards at some future date, let us say, either 2 or 3 years from now, just based on your understanding of the automotive industry?

What kind of a fuel penalty are we talking about between those alternatives, given a kind of 2- or 3-year horizon?

Mr. DUNHAM. We would basically agree with Mr. Train's testimony, sir. This chart, if I may hold it up, that he introduced——

Mr. ROGERS. Yes, it was introduced in the record by him.

Mr. DUNHAM. And I believe that we would support, basically, what these numbers would show. In other words, there is——

Mr. HEINZ. Which is, there is a small fuel penalty for 1976?

Mr. DUNHAM. That is right.

Mr. HEINZ. Compared to what we have in the interim 1975 standards, but a modest fuel penalty?

Mr. DUNHAM. Indeed, sir.

Mr. HEINZ. Based on your experience, you believe that to be accurate?

Mr. DUNHAM. We believe that to be a very modest penalty, particularly in light of the alternatives, because if you do not impose this kind of a penalty, then, if you look at the bottom line here, the thermal-reactor penalties and the other types of EGR methods used to control, then you do have a very substantial fuel penalty in that case.

Mr. HEINZ. That is a well taken point.

Let me just ask this. When you say you support Mr. Train's analysis, is that based on Mr. Train's analysis or your own personal experience in your companies and with the people you work with in the industry?

Mr. DUNHAM. The latter. It supports the research that we have done independently.

Mr. HEINZ. That is very helpful to know.

Mr. Chairman, I thank you. I have no further questions.

Let me just take this opportunity to thank the witnesses. They have been excellent and most helpful. Thank you.

Mr. ROGERS. Doctor, is there a great fuel penalty going into lead-free gasoline?

Mr. HAENSEL. May I present, or may I refer you, Mr. Chairman, to the table that we have submitted with our presentation.

[Table referred to follows:]

UNIVERSAL OIL PRODUCTS CO., DR. VLADIMIR HAENSEL, DEC. 4, 1973

Research octane number	Crude required barrels in excess of 100 barrels	Barrels of (2) needed for internal refinery energy	Barrels of crude converted to other forms of energy, LPG and natural gas (2) minus (3)	Relative crude barrels required for equal amount of driving	Barrels gain due to better efficiency 100 minus (5)	Net gain in barrels (6) minus (2)	Total energy gain in barrels (7) plus (4)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
89.5	0	0	0	100	0	0	0
92.0	.8	.1	.7	95.2	4.8	4.0	4.7
94.0	1.6	.25	1.35	92.2	7.8	6.2	7.55
96.0	3.3	.7	2.6	89.4	10.6	7.3	9.9
97.0	5.5	1.4	4.1	88.6	11.4	5.9	10.0
98.0	8.7	2.7	6.0	87.5	12.5	3.8	9.8

Mr. HAENSEL. I am sorry that Mr. Satterfield is not here, because he has been asking that question.

This table relates to a research octane number, as our first heading, and then goes on to the crude requirement above the 89.5 level, and then we speak of the barrels needed for internal refinery upkeep; in other words, the energy requirement.

Mr. ROGERS. That they have to accomplish this?

Mr. HAENSEL. That is right.

And then we see the barrels of crude that are converted to other products, such as LPG and natural gas, in the course of making the higher octane material.

Mr. ROGERS. Yes. All right.

Mr. HAENSEL. And then we talk about the relative crude barrels required for equal distance of driving. Everything is put on the same basis. And then we talk about the barrels gained due to better efficiencies. And this better efficiency is due to the fact that you can have a higher compression ratio at the higher octane level—and you may wish to put down some numbers—that at 92, you have approximately 8.7 compression ratio, whereas at 97 you will have about 10 or better compression ratio. And between these two compression ratios you gain something of the order to 10 or 11 percent in fuel economy.

So that what you really have is that you need more crude to make the higher octane gasoline, but you gain more by having to use less gasoline because of the higher economy of the driving.

Mr. ROGERS. Give me that once more.

Did you get that, Mr. Heinz?

Mr. HEINZ. I think so, but——

Mr. ROGERS. Could you repeat that once more, that last?

Mr. HAENSEL. OK.

Now, as you increase the octane number, more crude is required to make this higher octane gasoline.

Mr. ROGERS. Right.

Mr. HAENSEL. But you less of this high octane gasoline; to a greater extent, you use less of it. Therefore, you have a net gain.

And if you look at the final item, 8, the total energy gain is actually tremendous in terms of barrels. And you notice that we peak out at about 96 to 97 octane number as our most economical situation. And I think this is really a very significant thing, and I am sorry that Mr. Satterfield is not here, because I think this is something he would have enjoyed hearing.

Mr. ROGERS. I am sure he would have.

Mr. LEVENTHAL. Mr. Chairman, may I add a postscript to the very learned explanation, and one thing, and that is that a refinery is basically a closed loop. You do not lose crude; you lose volumes of gasoline, but the other products come off as gases. For example, the last time we appeared before you, when Governor Love was here, Mr. Nelsen was very concerned with propane for drying the farmers' crops. One of the things that you gain is propane, ethane, and other things. You have no net loss.

Mr. HAENSEL. The only net loss you have here, Mr. Chairman, is what is shown in column 3, and at the 97 octane number, you lose at the most 1.4 barrels, but the total gain is 10 barrels.

Mr. ROGERS. I see. For gas.

Mr. HAENSEL. Exactly.

Mr. ROGERS. Thank you so much. We are grateful to you for appearing, and the Chair also states we are grateful to Mr. Heinz from Pennsylvania, as well as other members of the committee.

The committee now adjourns at 8:03 p.m. and we will reconvene at 9 in the morning, Mr. Heinz.

[Whereupon, at 8:03 p.m., the subcommittee was adjourned, to reconvene at 9 a.m., Wednesday, December 5, 1973.]

NEW MOTOR VEHICLE EMISSION STANDARDS AND FUEL ECONOMY

WEDNESDAY, DECEMBER 5, 1973

House of Representatives,
Subcommittee on Public Health and Environment,
Committee on Interstate and Foreign Commerce,
Washington, D.C.

The subcommittee met at 9 a.m., pursuant to notice, in room 2322, Rayburn House Office Building, Hon. Paul G. Rogers, chairman, presiding.

Mr. Rogers. The subcommittee will come to order, please, to continue our hearings regarding the Clean Air Act in conjunction with the energy crisis.

Our first witness this morning is the Honorable Richard H. Ichord of Indiana. Welcome, Mr. Ichord. Please be seated and proceed as you see fit.

STATEMENT OF HON. RICHARD H. ICHORD, A REPRESENTATIVE IN CONGRESS FROM THE STATE OF INDIANA

Mr. Ichord. Mr. Chairman, the reality and apparent severity of the energy crisis has forced us to stop and reevaluate many of the steps we have taken in the name of environmental protection and anti-pollution. We ask ourselves if our zeal to solve one problem has led us to participate in an even greater problem.

Specifically, we must ask ourselves how much the installation of emission control devices on our cars contributed to the fuel shortage now staring us in the face. One of my Missouri constituents informed me that he increased his gasoline mileage from 6 miles per gallon to 13 mile per gallon by having his emission control devices disconnected on a 1972 model car. Other constituents have estimated that they have saved from 15 to 50 percent by following the same procedure. The three major automobile manufacturers range from 5 to 13 percent in assessing the fuel penalty resulting from the emission control devices installed on the 1970 to 1974 models. Each of them admits that these estimates are on the conservative side.

Edward Cole, president of General Motors, in response to questions about the reduced fuel consumption brought about by emission controls offered the following information: If four steps were taken in removing some of the emission controls, specifically (1) advancing the spark setting, (2) revising the vacuum advance mechanism, (3) removing the transmission control spark switch (TGS), and (4) removing the exhaust gas recirculation system (EGR) this could result in saving as much as 128.6 million barrels of crude oil per year. His figures were based on a 5-percent saving of fuel in the 110 million cars on the road that are 1970 models or later. If we estimate a 10-percent saving, which seems to be more realistic in view of the accumulated figures I have seen, this would mean that we could save as much as 257.2 million barrels of crude each year. This would amount to approximately 40 percent of our daily oil shortage.

The four steps mentioned by the GM president would leave intact certain emission controls including the vapor cannister and the positive crankcase ventilation valve (PCV) which are among the more effective pollution control devices on the new model cars.

We all want the cleanest air possible but this entire area is filled with so many uncertainties and unknowns. In a 1972 report to Congress, the Environmental Protection Agency said that health benefits from the controls on motor vehicles in effect could not be determined because "of an almost complete lack of data" establishing the health effects of carbon monoxide, hydrocarbons, and oxides of nitrogen at ambient levels. We have also been told recently that while the automobile does produce up to two-thirds of man-made carbon monoxide that nature itself produces about 10 times as much carbon monoxide as all the industrial and automotive sources combined. Natural sources also produce about six times the hydrocarbons and 15 times the oxides of nitrogen that man produces.

Mr. Chairman the need to pursue both long- and short-term measures to improve and protect our environment is of paramount importance. The fuel shortage is real and upon us. It seems reasonable to me that we consider relaxing the requirements for emission control devices on our cars until we have found some long term solution to our energy crisis.

Thank you Mr. Chairman.

Mr. ROGERS. Thank you, Mr. Ichord, for sharing your thoughts with us this morning. The committee appreciates your concern.

Mr. ICHORD. It has been my pleasure, Mr. Chairman.

Mr. ROGERS. We are pleased to have with us this morning Mr. John Sawhill, the Acting Deputy Administrator of the Federal Energy Administration, Executive Office of the President.

We welcome you to the committee, and we congratulate you while also giving you some of our sympathy in undertaking this job, which is not an easy one. However, we know that you will do a good job. We will be pleased to receive your statement at this time, sir.

STATEMENT OF JOHN C. SAWHILL, DEPUTY DIRECTOR, FEDERAL ENERGY OFFICE, EXECUTIVE OFFICE OF THE PRESIDENT; ACCOMPANIED BY BART HOLADAY, DIRECTOR, OFFICE OF ENERGY DATA AND ANALYSIS, DEPARTMENT OF THE INTERIOR; AND JOHN FALLON, CHIEF, SPECIAL STUDIES DIVISION, OFFICE OF ENERGY DATA AND ANALYSIS

Mr. SAWHILL. Thank you very much, Mr. Chairman, members of the committee. I am happy to be here this morning because this is a very important matter we are discussing, and I hope we can make a contribution to it.

I think just by way of perspective, that when the Clean Air Act was passed in 1970 to establish rigid auto emission standards, it basically focused on one problem—that is, air pollution—and I believe very strongly that we must maintain momentum toward this important goal of reducing air pollution. I also think that it is essential that we recognize some other vital priorities, one of which is efficient use of energy resources. Therefore, I think, as I said at the outset, it is very timely that your subcommittee has decided to address this subject and its impact on energy.

Mr. ROGERS. I might interrupt just to ask you to introduce your colleagues for the reporter.

Mr. SAWHILL. Yes, sir, two gentlemen from the Department of Interior, Bart Holaday and John Fallon.

Mr. ROGERS. We welcome you gentlemen to the committee.

Mr. SAWHILL. Thank you.

I would like to point out there is a certain amount of uncertainty surrounding some of the information that bears on the relationship between controls on automobile-related pollutants and petroleum requirements. Agencies of the executive branch are working to develop better information and resolve differences in order to provide a rational basis for decisionmaking in this area.

In my statement this morning, I am going to briefly address three topics: First, our current estimates of the shortfall of petroleum products; second, the potential energy impact of modifying pollution control systems on existing cars; and third, alternative emission standards for 1975 and future model automobiles, including the impact of lead-free gasoline on petroleum requirements.

PETROLEUM SHORTFALL

First the petroleum shortfall. We have done a lot of talk about this recently. We know that gasoline requirements are about 36 percent of the total oil demand; essentially all of this gasoline is used by cars, trucks, and buses. Any increase in efficiency of gasoline usage, therefore, can have an important effect on our overall energy picture.

Current Interior Department estimates [1] are that the total petroleum product deficit in the first quarter of this year will be about 3½ million barrels a day. The gasoline deficit will be about 700,000 barrels a day, or 11 percent of the unrestrained gasoline demand; in other words, the demand that would have taken place in the first quarter of 1974 had we not had the Arab embargo. If a proposed refinery shift to produce less gasoline and more heating oil and residuals is adopted, and we believe it should be, the shortage of gasoline will be about 1,400,000 a day, or 21 percent. It will be necessary to reduce the use of private automobiles by about 24 percent and the use of business and Government vehicles by 15 percent to achieve this overall 21-percent reduction.

If an embargo continues, shortfalls of roughly the same magnitude are likely to persist for the remainder of 1974 and 1975.

So that kind of gives us a backdrop of the problem we face in the gasoline area.

[1] "The Impact of Oil Interruptions on U.S. Energy Usage," Department of the Interior, Office of Energy Data and Analysis, Nov. 21, 1973.

EXISTING CARS

Preliminary estimates have been made by several automobile manufacturers, and work is underway in several Federal agencies, to determine what improvements in fuel economy could be achieved by modifying and retuning engines on existing cars that are equipped with emission control systems. More work is needed on this issue. However, the president of one automobile manufacturer stated that about half the mileage lost due to emission control systems could be recovered. The amount of recovery would vary from one model and year car to another. But if this estimate is correct, there could be a 4-percent increase in fuel economy for the 1970–74 car fleet, assuming that present driving patterns are maintained and that adjustments are made by competent mechanics.

This action could save 100,000 barrels of gasoline a day at current consumption levels if implemented at once. This is about 15 percent of our estimated shortfall. However, exhaust emissions would increase as the engines are retuned for better fuel economy, and overall hydrocarbon emissions would increase one-sixth and carbon monoxide by one-quarter. This may be too high a price to pay for better fuel economy, and I think it is.

FUTURE CARS

Now, let us look at future cars. Dramatic improvements have been made in the control of automotive emissions in the past decade. The current 1973–74 model cars emit less than one-third as much carbon monoxide and hydrocarbons per mile as the pre-1968 cars, for the oxides of nitrogen. Industry and EPA estimates indicate that there has been as much as a 35-percent reduction.

There are a number of alternative approaches to the emission standards that could be adopted. They range from no controls for the 1975 model cars to adoption of the 1975 statutory requirements.

I would like to just discuss three of these possibilities: First, that the present 1973–74 standards be maintained through the 1975 model year; second, that the 1975 interim standards be maintained beyond 1975, perhaps through the 1976 and 1977 model years; and finally, that the 1975 statutory standards be imposed in the 1976 model year.

If the present 1973–74 standards are maintained for an additional model year so that auto companies are not forced into making another major change in emission controls, they would have time to concentrate on improving fuel economy. We have tried to obtain estimates of potential savings but have no hard data at this time. Representatives of two automobile companies have indicated that improvements in fuel economy of at least 3 percent could be obtained in 1975 over current levels if the 1973–74 standards are continued through 1975. Such a 3-percent increase in fuel economy would apply to about one-tenth of the car-miles driven and would result in savings of about 10,000 barrels per day averaged over the first year. This savings would triple if maintained for a second year, assuming no further product improvement. So that is the first alternative in the way we assessed the energy fact of that.

A second alternative is to allow the 1975 interim standards to stand beyond 1975. The 1975 interim standards require reductions of hydrocarbon and carbon monoxide emission levels to approximately one-half of the previous year's levels. This means that cars meeting 1975 interim standards would produce about one-sixth as much of these pollutants as uncontrolled cars. The maximum allowable levels for oxides of nitrogen in the 1975 interim standards are the same, as you know, as in the 1973–74 standards.

The fuel efficiency changes associated with the emission controls necessary to achieve interim 1975 standards are uncertain. General Motors estimates that their 1975 catalytic converter system would permit a 13-percent improvement in fuel economy over 1973 model cars. However, it should be recognized that part of the improvements in fuel economy predicted by General Motors is due to changes such as high energy ignition systems, new carburetors with precision metering control, and steel-belted radial tires. We do not yet have specific data on the amount of the improvement that is attributable to the presence of the catalytic converter alone, but it could be less than one-half of the 13 percent.

The interim 1975 standards for California require the use of catalytic converters on most domestically produced cars. In addition, auto manufacturers have indicated that catalysts would be used on many of their cars sold in other States. This is important from an energy viewpoint because cars equipped with catalysts must use lead-free gasoline. There is a considerable crude oil penalty requirement associated with the manufacture of lead-free gasoline in the refinery. The impact of changing to lead-free gasoline affects all facets of the production and use of gasoline. Of course, this is another factor that has to be brought into the equation.

Unleaded gasoline requires greater process severity to produce higher octane materials: This results in a net loss in gasoline yield per barrel of crude. To produce lead-free gasoline at the required octane level will reduce the yield in the range of 1 to 3.5 percent.

One important point from the above is that the projected net increase in fuel economy due to the catalyst will be offset in large part by the crude penalty associated with the manufacture of lead-free gasoline. In other words, I said that we would achieve—General Motors estimated this—13 percent. If you take out all of the other factors, the factors not associated with the catalyst, that cuts it down to less than half. And then when you take out the lead factor, you are down to very little fuel savings.

In addition, it should be recognized that the production of unleaded gasoline requires the use of other substitute additives, such as aromatic hydrocarbons, benzene. The aromatic content of unleaded gasoline is expected to average 6 percent greater than that of leaded gasoline. Thus, 6 percent more aromatics are required. All or part of this quantity reduces the feedstocks available to the petrochemical industry. We are receiving indications from the petrochemical industry that feedstock shortages are becoming severe.

There may be a further penalty associated with the use of catalysts because of the possible health hazards associated with the accelerated formation of toxic sulfates. If catalysts are used and it is concluded that sulfates must be reduced, the primary alternative being considered at this time is to remove sulfur from gasoline. This would involve an additional fuel penalty of up to 2 percent of crude.

Summarizing all the above points with respect to the 1975 interim standards, it appears that the total fuel savings related to the use of these standards will range between 1 and 4 percent in terms of barrels of crude. Assuming that 10 percent of the total car-miles are driven by new cars, this savings will be between 8,000 and 32,000 barrels of crude per day averaged over the whole year. For a second year, these numbers will triple.

The third alternative is to introduce the 1975 statutory standards in 1976. Under this alternative, the allowable emission levels in 1976 would be approximately one-quarter of the 1975 interim for hydrocarbons and carbon monoxide. EPA has proposed setting a NO_x standard of 2.0 grams per mile for 1976, a reduction from the 3.1 grams per mile 1975 Federal interim standards. This requires increased circulation of exhaust gases and involves a fuel penalty. The fuel penalty associated with these changes has been estimated by General Motors to be more than 15 percent. This may be an unacceptable fuel penalty in order to further reduce emissions by this amount.

The introduction of catalytic reactors to remove emissions is a controversial subject because of the implications of the requirement that no lead can be used in the gasoline. Other concepts, such as stratified charge engines, while still under development, do not have this no-lead requirement which therefore allows the use of lower clear pool octane.

In summary, from the standpoint of efficient use of our energy resources, several conclusions might be reached: First, the 1973–74 standards should be frozen for several years if the fuel savings realized from the use of catalytic converters are more than offset by the crude penalty associated with the removal of lead from gasoline. Second, the 1975 interim standards should be extended for several years if (*a*) the potential fuel savings estimated for the catalysts are realized or (*b*) the fuel penalty associated with moving in 1976 to the 1975 statutory standards is as high as it has been estimated by some automobile industry representatives. Three, the 1975 statutory standards should be adopted for 1976 if the fuel penalty turns out to be small or if the reduction in emissions is important enough to justify the fuel penalty.

I fully recognize that we must balance our energy and our environmental objectives. Based upon the presentations and analyses available to me at this time, I conclude:

First, that the extension of the 1975 interim standards to model year 1976 and 1977 optimizes the balance between the objectives of reducing energy consumption and reducing atmospheric pollution; and second, additional study should be made of the possibility of freezing the 1973–74 standards.

Thank you, Mr. Chairman.

Mr. ROGERS. Thank you very much, Mr. Sawhill.

I might say to the committee that Mr. Sawhill has to be at the White House for a Cabinet meeting, so if we can question as quickly as possible, it would be helpful.

Mr. Satterfield.

Mr. SATTERFIELD. Thank you, Mr. Chairman.

I would like to invite your attention to page 9 of your statement. You are summarizing fuel savings due to the standards and you are talking about the 1975 interim standards. You say the range would be between 1 and 4 percent.

Would you explain to me how you get that 1 to 4 percent?

Mr. SAWHILL. Yes.

Mr. FALLON. This is a very optimistic estimate of the savings. Several people, automotive people, would feel there would be a net loss resulting from going to the 1975 interim standards. However, to be on the side of conservatism, we have taken this value.

The way we have reached it is this. Assuming basically that not all the 13 percent claimed by General Motors use of catalytic converters is actually due to use of the catalytic converter, we have used a figure here of about 6 percent. Of that 6 percent, we feel that the worst case, 1 percent, may be offset because of the requirement to use a nonleaded fuel. There is also basically some sulfur penalty. We do not know what that figure is at the moment.

If, on the other hand, the lead penalty, the penalty to provide nolead fuel is as high as 4 percent, we are reaching toward the lower range here.

Now, it might be fair to say, in fact, that other auto manufacturers feel that it is a standoff. There is no savings due to the use of these catalytic converters.

Mr. SAWHILL. So basically we took the 13 percent; from that we subtracted 6 or 7 percent because we feel that those savings could be achieved anyway, regardless of the catalyst, things like radial tires and other things. We have then arrived at a figure of 6 or 7 percent. From that we subtract the lead savings, which ranged between 1 and 3 percent——

Mr. SATTERFIELD. I follow that, but what I am interested in is why did you pick General Motors and ignore the other two?

Mr. FALLON. We picked General Motors so that any conclusions that we reached as a result of this would be on the most optimistic estimates.

Mr. SATTERFIELD. Well, do you think that is a proper way to go about it? General Motors does not produce 100 percent of the automobiles.

Mr. SAWHILL. No; they do not. We are really trying to give you a case about which there could be very little argument.

In other words——

Mr. SATTERFIELD. I think there is a great deal of argument.

Mr. SAWHILL. Yes.

Mr. SATTERFIELD. You pick 13 percent. Your premise is subject to argument.

Mr. SAWHILL. Well, maybe we are not expressing ourselves very well. The 13 percent number was picked to show the committee that even if you picked the most optimistic fuel savings, it still did not appear that there was much savings.

Mr. SATTERFIELD. Yet you are willing to make your final decision on that basis, are you not, when you say finally that you believe an extension of the 1975 interim standards would be acceptable.

Mr. SAWHILL. No. I said on the basis of the information available to us now, that appears to be the best approach, but we are also suggesting that we and the committee take a careful look at the possibility of freezing the 1973–74 standards.

Mr. SATTERFIELD. Let me ask you this question.

When you talk about a penalty for nonleaded gasoline, you are talking about a penalty in the crude oil barrel, are you not?

Mr. SAWHILL. Yes.

Mr. SATTERFIELD. Is the 1-percent penalty there offset by a 1-percent increase in gas consumption in the automobile?

Mr. SAWHILL. I am not quite sure I follow that question.

Mr. FALLON. No; it is not directly offset one for one.

Mr. SATTERFIELD. All right. That what did you subtract as far as this penalty is, from the 6 percent of whatever you came up with to arrive at this 1 to 4 percent in terms of penalty?

You did not offset percentage for percentage, did you?

Mr. FALLON. No.

Mr. SATTERFIELD. You weighted the percentages?

Mr. FALLON. OK, what we did, sir, is take the most pessimistic estimate and the most optimistic estimate.

Mr. SATTERFIELD. I realize that, but were you taking a percentage penalty—they say there is a 3-percent penalty in the barrel. You were saying that this 3 percent is equivalent to a 3-percent savings in the automobile?

Mr. FALLON. Well, there are two approaches to this. One is that even though at the present time one barrel of crude produces maybe 45 percent of a barrel of gasoline, the remaining 55 percent is not lost to the country.

Mr. SATTERFIELD. I am not talking about that. We are talking about the percentage of savings by putting a catalytic device on an automobile. We say we are going to save fuel, that is, fuel which runs from the tank of the automobile, it is an increase over its present rate.

Mr. FALLON. Yes.

Mr. SATTERFIELD. If that increase in mileage is 1 percent, is that the same thing as a 1-percent penalty in a barrel of crude to produce nonleaded gasoline?

Mr. FALLON. Basically at this point in time, if we had, say, a deficit of 1 million barrels of gasoline a day, we would have to import in the margin 1 million extra barrels of crude, because at the margin the refinery can make small enough changes to account for this slight shift.

Another way of looking at it—and I suspect this is what you are getting toward—it may be argued that if we had a deficit of an extra million barrels of gasoline, one would have to import 2 million barrels of crude.

Mr. SATTERFIELD. What I am getting at is if somebody claims you are going to increase the mileage in gasoline consumption in an automobile by 1 percent, is that 1 percent equivalent in numbers of gallons to the 1-percent penalty there is to make nonleaded gasoline from a barrel of crude; is the volume in the total amount of gasoline the same?

Mr. SAWHILL. I think there are two answers to that question. If you are short 1 million barrels of gasoline a day——

Mr. SATTERFIELD. All right, I give up. Apparently you do not get my point.

Let me put it this way. I get 10 miles a gallon in my automobile and I increase my efficiency 1 percent. I am saving 1 gallon a mile.

Right?

Mr. SAWHILL. Yes.

Mr. SATTERFIELD. Is that 1 gallon a mile going to offset the 3-percent penalty it costs to that barrel of crude to produce the nonleaded gasoline that I ran through there?

Mr. FALLON. Not at 3 percent, sir.

Mr. SATTERFIELD. Well, we have got some testimony that says it is 3 percent.

What percent do you think it is?

Mr. SAWHILL. Well, I think the issue was the 1 percent and the 3 percent would not offset each other.

Mr. SATTERFIELD. Well, 1 percent or 3 percent, are we talking about the same quantity on the one hand that we are talking about in the other?

Mr. SAWHILL. No. We are talking about—it is twice as much.

Mr. SATTERFIELD. Did you weight, then, the figures that you——

Mr. SAWHILL. No; these figures are not weighted.

Mr. SATTERFIELD. Then the 1 to 4 percent could be off as much as 50 percent then.

Mr. SAWHILL. Yes.

Mr. FALLON. However, you would receive the benefit of the extra residuals in that case.

Mr. SATTERFIELD. But not for gasoline.

Mr. FALLON. Not for gasoline.

Mr. SAWHILL. Not for gasoline, but if we look at our problem this winter, the immediate problem which most concerns me, it is not only gasoline that is in short supply, but it is all of the other products as well. Again, we are trying to show the committee that even if you make some very liberal assumptions about—and lean in the environmental direction, it still appears that at least you would want to freeze the 1975 interim standards and maybe go beyond that. I think that is the point we are trying to make.

Mr. SATTERFIELD. Yes.

I have some other questions, if we have any more time, Mr. Chairman.

Mr. ROGERS. All right, Mr. Nelsen.

Mr. NELSEN. Referring to the optimistic General Motors estimate of 13 percent, with which Ford and Chrysler did not agree, now are you really saying that Ford and Chrysler were more nearly on mark than General Motors?

Mr. FALLON. We did not, in fact, address ourselves to that question. However, the numbers that were available to us are that Ford feels it is a standoff. The catalyst does not of itself produce any increase in efficiency.

Mr. ROGERS. Well, now, if I may interrupt there, the testimony from Ford yesterday was a 3-percent benefit. Chrysler feels it is a——

Mr. FALLON. Pardon me. Yes; I am confused, sir.

Mr. SATTERFIELD. I would like to correct that, Mr. Chairman. Chrysler says they can increase by 3 percent if you do not go to the 1975.

Mr. SAWHILL. That is what we said, too. That is the point that we made in this testimony; yes, sir.

Mr. ROGERS. Well, they said the catalyst was a standoff.

Mr. NELSEN. I note you are speaking for the Executive Office of the President, and you deal with the total energy problem, do you not?

Mr. SAWHILL. Yes.

Mr. NELSEN. Today we are talking about just the automobile, but you deal in other areas.

Mr. SAWHILL. Yes.

Mr. NELSEN. I just want, for the purpose of the record, to call attention to something that came to my attention yesterday. There is a powerplant—and I think it is in Maryland, up in the mountains, far away from population centers, on top of a coal bed. Petroleum fuel is being transported to this plant, ignoring the coal, and all day long a train of trucks is going in there supplying the kind of a fuel that we need to heat our homes and to make our gasoline products, while the deposit of coal is ignored. I wish the Agency would review some of the savings that could be made by harnessing our coal natural resource, and, of course, I assume responsibility for what has been done because we passed the law that you are trying to administer.

So, do you have enough flexibility in your authority to, say, make use of this coal and save the petroleum products for other uses?

Mr. SAWHILL. We cannot force utilities to switch from oil to coal. We will strongly suggest that they do. We have identified 26 utilities in which we are going to urge to switch. In the emergency energy legislation we have asked for this authority and we hope that the Congress will give it to us.

If you could tell me the name of that particular plant, I would like to know.

Mr. NELSEN. Yes. I have the feeling now that this turn to the petroleum products from coal has been because of laws we pass and requirements that we create here. So my question is: Do we give enough authority to let them convert back to coal if they wish to do so, or do you need more authority by law to do it?

Mr. SAWHILL. We need more authority and I think we have asked for that.

Mr. NELSEN. Thank you very much.

Mr. SAWHILL. I would like the name of that plant, though.

Mr. NELSEN. I will get it. I do not have it at the moment, but I will get it.

Mr. SAWHILL. Fine, because we want to find all plants like that.

Mr. ROGERS. Mr. Preyer?

Mr. PREYER. I have just one question, Mr. Chairman, and I wish you luck, Mr. Sawhill. You have a very tough job ahead.

Mr. SAWHILL. Thank you.

Mr. PREYER. BPA apparently feels that it would be an unwise public policy to relax our goals for 1976 and 1977, without more data, because we should keep the pressure on for a clean environment.

I think the great virtue of the Clean Air Act, although there are a lot of mistakes in it, probably is that it has put tremendous pressure on the automobile industry and helped inspire these dramatic improvements which have been made in the past decade that you cite on page 4, and I think we do not want to lose that thrust of the Clean Air Act.

Mr. Train suggested that in line with this we should wait until this spring before making a final decision on carrying the interim 1975 standards over for 1976 and 1977 models.

Do you have any comments on the wisdom of that suggestion?

Mr. SAWHILL. It seems to me—and I am not an expert on the automobile industry—that you have got to give the automobile manufacturers a little more lead time than waiting until next spring. I would think you would have to come to a decision more quickly than next spring. The automobile companies that I have talked to have told me they need more lead time. They need a decision now, not a decision later.

On the other hand, I agree with Mr. Train that we want to keep the momentum going. We already have achieved some very significant reductions in emission limitations. I think the environmental movement does have a strong impetus behind it and we do not want to lose that, but I personally do not believe we would lose that by adopting the course that I have outlined here.

Mr. PREYER. Thank you. I appreciate that, Mr. Sawhill.

Mr. ROGERS. Dr. Carter?

Mr. CARTER. Thank you, Mr. Chairman.

I believe the three motor companies testifying here yesterday stated that it would be impossible for any of them to reach the 0.41 NO_x standards of 1977.

Do you agree that they are right about that?

Mr. SAWHILL. I have not really made a detailed study of it. I have talked to them and I have heard their statements on it. They seem reasonable to me, and I think EPA has also indicated they feel that would be very difficult.

Mr. CARTER. But yet they want to relax the standards.

Mr. SAWHILL. Has EPA not talked about going to a 2-percent level?

Mr. CARTER. No, sir.

Mr. ROGERS. I think they have.

Mr. CARTER. They may have talked about it, but they did not say it here.

Mr. ROGERS. I think they have.

Mr. CARTER. Well, 1977 standards, .41.

Mr. ROGERS. That is right, 1977.

Mr. CARTER. They recommended to continue as we are, did they not?

Mr. ROGERS. Except for NO_x.

Mr. SAWHILL. Except for NO_x.

I think there is an understanding of that.

Mr. CARTER. Well, it may be in the record.

Mr. ROGERS. I do not think they went into that particular item when we discussed it with them.

Mr. CARTER. The more efficient the engine is, actually, in burning CO and hydrocarbons, the more efficient the engine is, the more of NO_x, nitrous oxides are emitted. It constitutes quite a problem. After we reach the 1975 levels, there will be an increased penalty of gasoline in reaching these standards.

Is that not correct, the NO_x standards? These will be increased in amount?

Mr. SAWHILL. Yes.

Mr. CARTER. And already we have increased the gas penalty by our EPA legislation greatly.

Is that not correct?

Mr. SAWHILL. Yes.

Mr. CARTER. It was refreshing yesterday to have an automobile dealer, one who is where the action is and gets the reaction of the people, to testify before this committee. He stated, which I commonly hear from citizens, that Congress has made a serious mistake in going too far too fast.

Suppose that we do accept the 1975 standards. Well, General Motors said there would be approximately 13-percent fuel gain.

Is that correct?

Mr. SAWHILL. That is what they said, yes.

Mr. CARTER. Even with such a gain as they say, will we obtain as much mileage from our cars as we did in 1971?

Mr. FALLON. No, it does not quite get back—oh, 1971, sir.

Mr. SAWHILL. It does not get back to 1968.

Mr. FALLON. It does not get back to 1968. It does, in fact——

Mr. CARTER. Does exceed 1971?

Mr. FALLON. Yes.

Mr. CARTER. Thank you, Mr. Chairman.

Mr. ROGERS. All right, Mr. Symington.

I might say I am going to try to get every member here a question or two if we can. We do not have much time left.

Mr. SYMINGTON. Thank you, Mr. Chairman.

I think this is a very fine statement. It has put a lot of things in perspective. There are still questions you need to get answered for yourselves as well as us.

Mr. SAWHILL. Yes.

Mr. SYMINGTON. If it comes down to the question of whether to go with the freeze of the 1973, 1974, or to go to the interim 1975, that seems to be the only real option.

Mr. SAWHILL. That is a question in my own mind that I have not quite resolved and I am trying to.

Mr. SYMINGTON. With respect to the freeze, 1973–74, you have a very rough estimate of 10,000 barrels a day.

Mr. SAWHILL. That is based on the 3 percent.

Mr. SYMINGTON. Yes.

And you do not have an estimate yet for going ahead with the 1975 interim standards, on page 7, you are not sure you have——

Mr. SAWHILL. Well, we said 1 to 4 percent, but as Mr. Satterfield pointed out, there are some problems with that estimate.

Mr. SYMINGTON. Yes, and of course it is also connected with the catalytic converter. You are factoring that possibility into the interim 1975.

Mr. SAWHILL. Yes, that is correct.

Mr. SYMINGTON. And you point out that in addition to everything that has been discussed about the production of unleaded gasoline, you are going to lose 6 percent aromatics that would otherwise be available to the petrochemical industries.

Mr. SAWHILL. Yes, that is terribly important.

Mr. SYMINGTON. I think that is vital, too. I think that is extremely important because they are already showing signs of instability and concern.

Mr. SAWHILL. Yes, we are very concerned about the petrochemical industry. It is a very vital industry in the country.

Mr. SYMINGTON. And I guess we still look to you, I think we do have to resolve this, Mr. Chairman, you know, in the next couple of weeks or so, and we are going to look to you for last-minute advice as to the net advantage of catalysts as projected for the interim 1975 standards.

Mr. SAWHILL. Yes. You know, I am one day old in my job. We are hard at——

Mr. SYMINGTON. Let me say, I hope you keep it now because we had Mr. Dibona here a week ago and he made all kinds of promises to us that he would deliver yesterday and he disappeared in the meantime. So——

Mr. SAWHILL. Well, I hope I can do better.

Mr. ROGERS. Thank you.

Mr. Hastings.

Mr. HASTINGS. Thank you, Mr. Chairman.

Mr. Sawhill, you used the word "uncertainty" on page 2, and I guess you probably echo what this subcommittee probably strongly feels.

Mr. SAWHILL. Yes.

Mr. HASTINGS. I will not recite the litany of differences that have been recited to the committee between the automobile manufacturers, the petroleum people, and the catalytic converter people who all, of course, have a peculiar area of vested interest, but your conclusions are, it seems that we should then adopt the 1975 standards for 1976, 1977.

Mr. SAWHILL. Yes.

Mr. HASTINGS. And yet you still say that we ought to take a look at 1973–74 standards.

Mr. SAWHILL. Yes.

Mr. HASTINGS. We are under certain pressure to move rather quickly since there are some who feel we should amend the Emergency Energy Act with this amendment to the Clean Air Act.

Mr. SAWHILL. Yes.

Mr. HASTINGS. This is supposed to be concluded in full committee by this Friday.

The concern that I have is that if we do in fact go to the 1975 standards for 1976–77 by an amendment to the Clean Air Act, then perhaps a careful analysis of whether or not we should go back to 1973 or 1974 may be academic.

Mr. SAWHILL. Yes, it would be.

Mr. HASTINGS. Since the very problems you raised, the questions in relation to unleaded gas or leaded gas, as I understand it, the auto manufacturers would have had to proceed with the converter.

Mr. SAWHILL. Yes.

Mr. HASTINGS. Therefore, that question of the study of 1973–74, as I mentioned again, could be very well academic.

Could you enlarge on that?

Mr. SAWHILL. I guess the way I feel is that one of the most important things is to make a decision and to take the uncertainty out of it. I think by freezing the 1975–76 standards for the period through 1977, you give the industry a chance to spend a few years adjusting to this level.

Mr. HASTINGS. Well, all right, I understand that.

Now, then, do you think we should do this by an amendment to the Emergency Energy Act that the full Committee on Interstate and Foreign Commerce is now considering marking up?

Mr. SAWHILL. Well, I think it depends on how certain you feel about the differences between 1973–74 and the 1975 interim standards.

Mr. HASTINGS. Well, that raises an awful lot of questions.

Mr. SAWHILL. It does raise a lot of questions.

Mr. HASTINGS. Thank you very much.

Mr. ROGERS. Dr. Roy?

Mr. ROY. Thank you, Mr. Chairman.

I am sorry I arrived late and I have not had a chance to read your entire statement.

Is there any question in your mind that all three automobile manufacturers can meet the 1975 interim standards?

Mr. SAWHILL. Oh, I think they can; yes.

Mr. ROY. So the question of leaded or nonleaded gasoline looms larger to you than the question of the ability of the automobile manufacturers to meet the interim 1975 standards.

Is that correct?

Mr. SAWHILL. Yes.

Mr. ROY. What communications—again in 1 day you cannot answer this—do you anticipate between EPA and the Office of the Energy Administrator?

Mr. SAWHILL. I think a great deal of communications because we are working on a common problem.

Mr. ROY. Do you have any explanation why somebody, someplace, in the White House asked that the interim 1975 standards be continued for 1976 and 1977 without consultation with the Director of EPA?

Mr. SAWHILL. I do not know if he was consulted on the specific request, although he was generally informed of the White House position.

Mr. ROY. He testified before us that he had not been consulted regarding that decision.

Mr. SAWHILL. Well, maybe he personally was not, but the Agency was.

Mr. ROY. Well, apparently he was unaware that the Agency had been consulted, so perhaps you are suggesting the communications——

Mr. SAWHILL. Maybe there is a difference between consulting and advising.

Mr. ROY. You think the communications gap was within EPA rather than between the White House and EPA?

Mr. SAWHILL. No, I do not think so. Maybe it was just a semantic problem. I think EPA was advised that the White House was considering proposing to the committee an amendment to the Clean Air Act that would be either 1973–74 or interim 1975.

Mr. ROY. Right now you feel that Mr. Train's recommendation to us is not acceptable?

Mr. SAWHILL. Well, as I understand it, his recommendation to you was that you study this, that you consider it outside of the Emergency Energy Act, but he has not gone as far as to suggest to you what course to adopt.

Mr. ROGERS. Yes, he did suggest no change.

Mr. SAWHILL. OK. Yes, I would say no change would be unacceptable from our standpoint.

Mr. ROY. Thank you.

Mr. ROGERS. Mr. Heinz?

Mr. HEINZ. Thank you, Mr. Chairman.

And I would like to ask a question in two areas, one with respect to the aromatics you mentioned on page 8, the other with respect to sulfur and sulfates on page 9.

Why are more aromatics required to make unleaded gasoline, to raise the octane level?

Mr. FALLON. Yes. The aromatics, the benzenes, and the toluenes intrinsically have a very high octane number, and by adding them to the unleaded lower octane pool——

Mr. HEINZ. Is it possible to raise the octane of unleaded gasoline by increased tracing?

Mr. FALLON. Up to a point, sir.

Mr. HEINZ. What is that point?

Mr. FALLON. It depends very much on the refinery. I think it is fair to say that if we were designing a refinery from scratch, some refineries that are already in existence, they can in fact produce these high octane unleaded pools without excessive use of aromatics.

Mr. HEINZ. What is a high octane, unleaded pool in research octane?

Mr. FALLON. In research octane, RON number, you get as high as 94.

Mr. ROGERS. May I interrupt just 1 minute before you proceed?

Mr. Sawhill is going to have to leave us. Is there any vital question you have to have, Mr. Hudnut?

Mr. HUDNUT. I wanted one. He could probably answer it in about 2 minutes.

Mr. ROGERS. All right, if you could do it quickly, if you do not mind, John, and then we will keep the others here to go into these details, if you can be with us.

Mr. HOLADAY. Certainly.

Mr. HUDNUT. I just wanted to ask if you were aware of the amendment that was adopted by the full committee yesterday relative to the Federal Energy Administration, and if so, does the administration support this amendment?

Mr. SAWHILL. I have not read the language. I have just heard by hearsay that this is an amendment.

Mr. ROGERS. I think perhaps if he could give us his comment for the record on that after he has an opportunity to study that it would be helpful.

[The information requested was not available to the committee at the time of printing—April 1974.]

Mr. HEINZ. Mr. Chairman, before Mr. Sawhill leaves——

Mr. SAWHILL. It is important. We do not want this Agency to be set up as an independent regulatory agency outside of the executive branch. It is terribly important that this be in the executive branch and in the administration because we are going to have to utilize the recourses and the agencies of the whole administration.

Mr. ROGERS. Well, I think we should try to keep the air for the moment.

Mr. HEINZ. Well, before Mr. Sawhill leaves, and this is a question that relates to air, are you aware, Mr. Sawhill, that yesterday there was an amendment accepted that I happened to oppose, that essentially gets the conversion portion of the bill?

Mr. SAWHILL. The conversion?

Mr. HEINZ. Section 104 of the Emergency Energy Act.

Mr. SAWHILL. I am not familiar with it.

Mr. HEINZ. Essentially, it means that you cannot take any action under 104 of the bill. I suggest that you take a look at it.

Mr. ROGERS. You might give us your comment on it.

Mr. CARTER. It is a planning part of it.

Mr. ROGERS. You can give us your comment on it. I presume you will give it to the full committee.

Mr. SAWHILL. Yes.

[The information requested was not available to the committee at the time of printing—April 1974.]

Mr. ROGERS. Now, let me just ask one question as you leave.

Mr. SAWHILL. Yes, sir.

Mr. ROGERS. What would you think of fuel economy performance standards?

Do you think we should require them? Fuel economy standards, in other words, to say the automobile companies should make their cars in such a way that they can get a certain number of miles to the gallon.

Mr. SAWHILL. Yes, I think it is an excellent idea.

Mr. ROGERS. You support that.

Thank you, Mr. Sawhill. We are grateful for your being here.

Mr. SAWHILL. Thank you. Excuse me for having to leave.

Mr. ROGERS. John, you may proceed.

Mr. HEINZ. Thank you.

You had mentioned, I believe, the high octane pool of 94 percent octane and research octane. Are you aware that you only need 91 percent octane for most vehicles?

Mr. FALLON. Yes. Let me just amplify the remark I was making. The current octane pool, lead-free octane pool, is about 88, 89. That could be raised with a 1-percent penalty to 91. It can be raised to 94 with a 4-percent penalty. No plants could reach that 94 with less of a penalty because they are specifically structured with performance to do that.

Mr. HEINZ. Thank you. I think that answers my questions on the section. It is very helpful.

With respect to sulfur, sulfur is not something that is in a catalyst. As I understand it, it is something that is in gasoline as a result of it being in crude oil.

You indicated on page 9 some concern about the sulfur in gasoline. Why do you believe that the sulfur that is in gasoline is any more hazardous after it goes through a catalytic muffler than it is when it goes through today's exhaust pipe?

Mr. FALLON. Excellent, excellent question. Basically what the catalyst does, is essentially accelerates the oxidation process that normally occurs with sulfur, what comes out of the exhaust of the normal car is sulfur dioxide, and in time, maybe 20 minutes after it is emitted from the car, normal oxidation process, which occurs slowly, will have occurred and it will be turned to sulfur trioxide. In the presence of moisture, this will become sulfuric acid, which——

Mr. HEINZ. That is with respect to present tailpipes?

Mr. FALLON. Yes, sir. Now, and in fact, because it takes 20 minutes to occur or so depending upon the ambient temperatures——

Mr. HEINZ. So in 20 minutes you get sulfuric acid from existing technology.

Mr. FALLON. Which is spread over a very large diffuse area.

Mr. HEINZ. OK, but it is diffused. OK.

Mr. FALLON. Now, in the catalytic case, which is an oxidizing catalyst, this oxidation process occurs virtually instantaneously and what comes out is a sulfur trioxide or a sulfate which in fact on a moist day can issue almost neat from the exhaust as sulfuric acid; and thereby you have a concentrated source of sulfuric acid, which may well be a serious problem. EPA is advising us on this.

Mr. HEINZ. If you use 10 to 13 percent less gasoline in the 1974 models as GM has testified, do you presumably generate 10 to 13 percent less either sulfur dioxide or sulfur trioxide?

Mr. FALLON. Yes; and depending on which of GM's cars we take, for instance, it will be essentially the same number except that if it is a catalyst-equipped car, it will come out in a concentrated form; if it is the normal type of car, it will be diffused over a large area before in fact it turns into sulfuric acid.

Mr. HEINZ. Thank you, Mr. Chairman.

Mr. ROGERS. Mr. Hudnut?

Mr. HUDNUT. No, sir, in the interest of time, thank you, I will defer.

Mr. ROGERS. I want to publicly make a statement about the members of this subcommittee who have been working hard and diligently all year long. The demands have been very heavy, and I want to commend and thank them publicly for their great interest, attention, and dedication to their jobs.

Mr. HASTINGS. We feel the same way about you, Mr. Chairman.

Mr. ROGERS. Now, let me just ask quickly, because we have one more witness, why should we always think in terms of increasing car mileage per gallon of gas rather than going to the problems that really bring the fuel penalty?

Why do you not suggest a limitation on weight of cars, or doing away with air-conditioners for a year, or other such things that really could bring some quick, fast fuel economy?

Mr. HOLADAY. I agree completely.

Mr. ROGERS. Well, now, give us something on that.

Mr. HOLADAY. The reason we did not, it was our understanding we were asked to testify on——

Mr. ROGERS. I understand, but it seems to me here everybody wants to say, "Let's take everything away and dirty up the air." Yet, they do not face the problem where we could really bring some fuel ecomony by doing something about weight, automatic transmission, air-conditioning, and other things in this area.

Do you think we should do that?

Mr. HOLADAY. Mr. Chairman, I hope that is not what you thought we said, because we certainly did not intend that.

Mr. ROGERS. All right, then. I want you and Mr. Sawhill to put in the record what you think we ought to do, and have Mr. Sawhill, too, as far as weight, and air-conditioners. We would also like to know what fuel economy that would bring about.

Mr. FALLON. We have discussed this with them, sir.

Mr. ROGERS. Do you not think this is a good idea?

Mr. FALLON. Yes; we just did not want to spread the scope of this investigation too far.

Mr. ROGERS. Well, we had better spread it because we have got to act.

Mr. CARTER. Mr. Chairman, on that theoretical basis it is quite clear that the extension of 1975 interim standards to model year 1976 and 1977 optimizes the balance between the objectives of the use and the energy consumption in reducing atmospheric pollution.

Mr. ROGERS. What I am saying is they are not addressing the weight problem or any of these others which really have an effect on fuel penalty.

Mr. HOLADAY. It certainly does.

Mr. SYMINGTON. Would the Chairman yield there?

Mr. ROGERS. Yes.

Mr. SYMINGTON. The transmission, too. They suggested the standard transmission saves maybe 6 percent or something like that.

Mr. ROGERS. Get us what can be saved and let us know. Could we do that quickly?

Mr. FALLON. Yes, sir.

[The information requested was not available to the committee at the time of printing—April 1974.]

Mr. SATTERFIELD. Would the chairman yield again?

Mr. ROGERS. Certainly.

Mr. SATTERFIELD. I would like to back up the statement by the gentleman here. I do not want to interpret anything that was said here this morning to suggest that we go back and take any antipollution devices off of automobiles. The retention of 1974 standards would not take anything off. It would leave on the automobile what you have on it right now. We are talking about whether they are going to put something else on.

Mr. ROGERS. Well, it is not going according to the law to clean up the air.

Mr. CARTER. Mr. Chairman.

Mr. SATTERFIELD. It isn't going to dirty it either.

Mr. ROGERS. Yes; it will dirty it.

Mr. CARTER. Mr. Chairman, if you would yield for just one thing.

Mr. ROGERS. Certainly.

Mr. CARTER. Actually, we are to increase the efficiency of the motor, which we all want to do, and save gasoline. We know that that creates a problem with NO_x, and according to the testimony of a vast majority of the people who have testified before us, including the gentleman from MIT yesterday, you cannot have them both. You cannot have increased mileage, increased efficiency without having increased amounts of NO_x. Of course I know that some other analysts did testify to that.

Mr. ROGERS. Yes.

Mr. FALLON. That is a matter of debate, sir. There are certain developments which may be 1, 2, or 3 years away, such as stratified charge engine. And if the claims we hear for it are true—and the Japanese company, Honda, is currently introducing it—these engines do, in fact, restore the high compression ratios we have been accustomed to, hence the concommitant efficiencies to go with them. They also run on——

Mr. HUDNUT. Mr. Chairman, would the chairman yield for a minute?

Mr. ROGERS. If you would put something in the record on that.

Mr. HUDNUT. When they insert that in the record I wonder if they could also address themselves to the pressure that the automobile producers seem to be under from DOT to produce a heavier car in order to make it safer.

Mr. ROGERS. Well, of course; it would have to be the discretionary area where they could reduce weight, and if you could point it out, I think it would be helpful.

Mr. HUDNUT. I appreciate that.

Mr. CARTER. Correction, Mr. Chairman, on one thing.

Mr. ROGERS. Yes.

Mr. CARTER. Although we referred to the stratified charge engine as Honda, it was developed at Stanford University actually.

Mr. FALLON. Exactly. I just read the article the other night.

Mr. ROGERS. Thank you for being here; we appreciate it. And if you will get in the comments we asked for as quickly as possible, it would be helpful, because I would like to have this record printed.

Mr. SATTERFIELD. Mr. Chairman.

Mr. ROGERS. Yes; and if anyone has questions they would like to submit, that would be fine, too.

Mr. SATTERFIELD. At this point I understand that the Public Works Committee in the Senate contracted a study by Dr. Samuel Epstein that deals with lead and lead additives in the gasoline. I wonder if we might not inquire as to whether that report is available over there; and if so, we could include it in the record here.

Mr. ROGERS. Yes. Would the staff check that report, please.

[Testimony resumes on p. 529.]

[The text of the Epstein report referred to follows:]

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12/21/73

POLICY OPTIONS FOR REDUCING PUBLIC HEALTH HAZARDS FROM COMBUSTION OF LEADED GASOLINE

A Report to

The Senate Committee on Public Works

Samuel S. Epstein, M.D.

I. ENVIRONMENTAL LEAD BURDENS FROM LEADED GASOLINE

A. U.S. Consumption of Leaded Gasoline

U.S. consumption of lead gasoline additives has increased from 37,000 to 262,000 tons over the period 1935 to 1968 (1). During this time there has been a proportional, besides absolute, increase in the consumption of lead in gasoline in relation to total lead consumption; in 1968, gasoline lead accounted for approximately 20% of all lead used in the U.S.

B. Environmental Emissions from Leaded Gasoline

The major source of emissions from leaded gasoline is exhaust particulates, which when sub-micron in size, remain primarily suspended and airborne, and when larger, particularly greater than 2μ, settle as dust-fall. Dust-fall particulates are likely to become re-entrained and secondarily airborne following grinding by traffic and weathering; however, this secondary source of airborne lead does not appear to have been generally considered. Additional sources of airborne lead are from lead alkyl gasoline additives, from both evaporative losses and spillages, especially around service stations, and from exhaust emissions of unpyrolysed alkyls. Alkyl emissions can be particularly high in poorly tuned cars starting cold and fully choked and can result in transient concentrations of up to 5 mg/m^3 (2). Lead alkyls are rapidly degraded in air to inorganic lead. Such alkyl losses are generally ignored in most inventories, particularly because of analytic problems. In this connection, it was stated in the "Three Cities Study" that "... alkyl lead concentrations did not reach 10% of the inorganic lead values and probably were considerably less" (3).

The estimate that inorganic lead emissions from gasoline combustion constitute 98% of total emissions from major specified sources (4) is commonly misquoted as referring to the percentage of total environmental sources. As the specified sources are only partial -- ignoring such sources as weathering and combustion of lead products, municipal incinerator effluents and external venting from manufacturing plants -- it appears likely that the 98% figure is an over-estimate, although this ignores incremental contributions from alkyl leads. A more reasonable estimate for the contribution of mobile source lead is in the region of 90% (5).

Besides alkyl losses, used engine oil has not received adequate consideration as a potential source of environmental lead. Only approximately 25% of used engine oil can be currently accounted for (5). High mileage studies suggest that approximately 11% of lead burned is retained in oil and oil filters; additionally, used oil contains approximately 30 ppm of benzo(a)-pyrene (5). Thus, combustion of used oil in stationary sources, such as incinerators and coke ovens, quite apart from improper waste disposal into sewage, represents significant increments in environmental lead burdens.

C. Environmental Burdens from Leaded Gasoline

A wide range of ecological data indicate that burdens of available lead in the biosphere have recently increased; leaded gasoline combustion is generally incriminated as the major source for such an increase. Isotope analysis has been used to differentiate natural from industrial sources of lead.

1. Glaciers

Studies on chronological layers of snow strata in quiescent ice sheets in Greenland indicate a rise in ice lead concentrations from less than 0.0005 µg/kg in 800 B.C. to greater than 0.02 µg/kg in 1965 A.D. (6); a steep exponential rise occurred after 1940 following increasing use of leaded gasoline.

2. Water

Lead concentrations in some surface waters in the Mediterranean and Pacific have recently increased to levels of 0.2 to 0.35 μg/kg, in contrast to pre-industrial levels of 0.02 to 0.04 μg/kg (7). Mean global natural lead content of lake and river waters is estimated to be 1 to 10 μg/l (8); however, recent analysis of 1,500 samples from natural water sources near treatment plants revealed that 27 samples were in excess of U.S. acceptable limits for drinking water of 50 μg/l (9). The contribution of emissions from outboard motors using leaded gasoline has not been investigated, although it is known that a 10 hp engine at one-half throttle emits approximately 229 μg lead/l of gasoline (10).

A correlation has been demonstrated between gasoline consumption and lead rainfall concentrations, with median and maximal concentrations of 10 and 300 μg/l, respectively (11). Lead is removed from air by agglomeration and precipitation and its residence time is calculated to vary from 7 to 30 days (12).

3. Plants

Chronological increases in lead concentrations of Swedish mosses, which mainly obtain their minerals from precipitation and settled dust, from 1875 to 1900 and from 1950 to 1968 have been related to increased combustion of coal and to the use of leaded gasoline, respectively (13); on a national basis in 1968, combustion of coal contributed approximately only 0.5% of cited lead emissions (4). While soil lead is generally poorly available to most plants (14), vegetation and grass growing close to highways may become contaminated with surface deposits which may produce an increase in lead body burdens of grazing cattle; such deposits can be partly removed from vegetation by washing. Various studies have demonstrated correlations between concentrations of lead in grass with proximity to highways and with concentrations of lead in air (15, 16).

4. Soil and Street Dust

Exclusive of areas near deposits of lead ores, the natural concentrations of soil and lead range from 2 to 200 µg/g, as a function of geological factors (15). Lead contaminates soil from dust-fall and rain-fall. For this reason, surface soil lead levels are markedly increased in commercial as opposed to residential areas and with increasing proximity to highways with high traffic density (17). Lead levels also markedly decrease with depth from the surface. Concentrations of lead in surface soils of city parks may be very high, reaching 3.4 mg/g in Los Angeles (18). The concentration of lead in street dust can also be very high; average concentrations in residential and commercial areas of 77 mid-western cities were 1.6 and 2.5 mg/g, respectively.

Grinding and weathering of street dust may result in its partial re-entrainment as airborne particulates. Additionally, leaded street dust can enter sewage systems and contaminate ground waters (19).

5. Atmospheric Lead

Natural background concentrations of lead in air are estimated as approximately 0.0005 $\mu g/mg^3$ (20), resulting from airborne dust averaging 10 to 15 ppm of lead and from gases diffusing from the earth's crust. There is a steep gradient in atmospheric lead concentrations from major urban centers, the concentrations generally depending on city size, to rural areas and to air over the mid-Pacific where concentrations are more than 100-fold lower than in urban centers (21). This gradient is very largely due to combustion of leaded gasoline. In 1968, atmospheric lead emissions in the U.S. from combustion of leaded gasoline were

181,000 tons in contrast to only 985 tons from smelting (4). Ambient lead concentrations in city air are closely correlated with traffic density and with heavy traffic hours; highest levels of lead in Los Angeles reach 38 $\mu g/m^3$, whereas mean midday levels downtown are 10.5 $\mu g/m^3$ (3). Progressive dilution of atmospheric lead increases with distance from highways. The "Three Cities Study" of 1961 to 1962 revealed that general urban concentrations ranged from 1 to 3 $\mu g/m^3$, with the highest concentrations in each city ranging from 6.4 to 11.4 $\mu g/m^3$ (3). More extensive National Air Sampling Network (NASN) monitoring of 217 urban stations in 1966 to 1967 revealed annual mean concentrations of 1.1 $\mu g/m^3$; however, samples averaged quarterly by individual sites yielded values up to 19 $\mu g/m^3$ (22). Contrastingly, non-urban stations near cities averaged 0.21 $\mu g/m^3$, in remote rural areas they averaged 0.022 $\mu g/m^3$, and in intermediate locations they averaged 0.096 $\mu g/m^3$.

Analyses of annual trends in atmospheric lead concentrations have yielded somewhat contradictory results, presumably, because of sampling and analytic problems. However, recent studies in San Diego, where measurements were based on weekly samplings at a single site besides on 1959 and 1966 NASN yearly averages of 1.1 and 1.8 $\mu g/m^3$, respectively, indicate that lead concentrations in the city air are increasing by as much as 5% annually (23). Additionally, more extensive preliminary data in the "Seven Cities Study" of 1968 to 1969 (24) indicate increases in average air lead concentrations for Los Angeles, Philadelphia and Cincinnatti of 56%, 19% and 17%, respectively, over the values recorded in the 1961 to 1962 "Three Cities Study".

Dispersion of lead from emission sources and atmospheric residence times are largely a function of particle size. Particles greater than 1 μ in size tend to settle as dust-fall relatively rapidly, whereas particles less than 1 μ tend to remain suspended as airborne lead. The Mass Median Equivalent Diameter (MMED) of lead particulates has been studied using various techniques. MMED values of 0.25 μ, determined by the Goetz spectrometer, have been reported for 59 urban sites (25). An identical weighted MMED average of 0.25 μ has been derived from the data of 5 independent investigations on ambient urban air (26). More recent and more extensive estimates indicate an MMED range for ambient lead of 0.2 to 1.43 μ (27); 59% to 74% of the mass of lead particulates in this study were less than 1 μ in diameter.

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II. POTENTIAL ADVERSE HEALTH EFFECTS FROM COMBUSTION OF LEADED GASOLINE

Increasing levels of lead particulate emissions resulting from combustion of leaded gasoline represent a significant major increment in available lead burdens in the biosphere (see Section 1C). This increased burden may pose adverse public health effects, particularly to infants and young children, in densely populated urban areas with heavy automobile traffic. The potential community hazards of airborne lead have been recently summarized in an EPA Document (1), with particular reference to the justification of the recent fuel additive regulations reducing gasoline lead levels (2, 3); while the EPA document has, on various grounds, been vigorously challenged (4-6), its objectives appear consistent with available data and with prudent public health policy.

A. Potential Lead Intake from Combustion of Leaded Gasoline

1. Inhalation

The role of inhalation is well recognized as the predominant route of occupational exposure, resulting in increased body lead burdens and in acute and chronic lead poisoning (7). It is also recognized as a cause of increased blood levels in children living in the vicinity of lead smelting plants (8) and in tunnel attendants and traffic policemen exposed for prolonged periods to automobile emissions (7). With regard to community exposures from automobile emissions, the potential respiratory intake of lead exhaust particulates is highly variable, reflecting factors including ambient airborne lead levels and air volume inhaled. Assuming ambient air concentrations of 2.5 $\mu g/m^3$, the median value for Los Angeles as determined in the "Three Cities Study" (9), and a daily inhaled volume of 6 m^3 for a one year old child, then a lead air intake level of 15 μg/day will be achieved (10); infants living downtown and close to traffic corridors, where ambient air lead can reach levels 10-fold higher than 2.5 $\mu g/m^3$, will have correspondingly higher inhaled lead burdens. It has been calculated that for an adult male doing light work for 8 hours a day and inhaling approximately

23 m^3 of air daily, although this volume may well be an over-estimate, there will be a corresponding, but proportionately, smaller intake of 57 μg/day (10).

There are various independent lines of evidence indicating that emissions of airborne lead, resulting from combustion of leaded gasoline, increase body burdens of lead, as indicated by increased blood lead levels, recognizing that these levels principally reflect only recent exposures. While each line of evidence is in itself not entirely conclusive, and some may even be debatable, the overall constellation data is sufficiently supportive, if not entirely conclusive, to warrant prudent public health policies designed to markedly reduce airborne lead emissions from gasoline combustion.

— The "Seven Cities Study" indicates that blood levels of adult females living in urban areas with higher lead levels are consistently higher than blood levels in adult females living in suburban areas (11).

— Adult women living in homes close to roads with dense traffic have higher blood lead levels than those living at greater distances (12). This "roadway study" is particularly significant as air lead measurements were also made at the front porch and inside the homes. Although air lead levels in homes close to roads were only 1 to 2 μg/m^3 higher than those further away, these higher exposure levels correlated with higher blood levels. Illustratively, the number of women living 12 feet away from roads with blood levels greater than 29 μg/100 g was significantly greater than such numbers in women living 125 and 400 feet away. Inferences from this "roadway study" appear more reliable than those from the "Seven Cities Study", where measurements of airborne lead were made at various air sampling stations which in some instances were at a considerable distance from the population cited. The importance of sampling site is stressed by recent findings that lead concentrations at 1.5 meters above the ground are twice those at 20 meters (13); this suggests that levels of inhalation intake by young children have been significantly under estimated. The results of this early "roadway study" have been recently confirmed in a group of 5,226 children in Jew Jersey (14). As indicated in the following table, a striking correlation was demonstrated between blood lead levels and proximity to roadways; while conditions of housing were not specifically investigated, these children lived in generally similar neighborhoods.

	% Of Children with Blood Lead Levels in Specified Ranges, µg/100g		
Distance from Roadway (feet)	< 40	40-59	> 60
< 100	42.6	49.3	8.1
100 - 200	72.4	24.2	3.4
> 200	68.4	26.9	4.7
"Citywide Expected Values"	65.1	29.9	5.0

Additional correlations were observed in 1,265 of these children, as indicated in the following table, between blood lead levels and traffic density.

	% Of Children with Blood Lead Levels in Specified Ranges, µg/100g		
Average Weekday Vehicle Density (Number Cars)	< 40	40-59	> 60
< 24,000	58.3	36.6	5.1
> 24,000	37.9	51.3	10.8

--- Air and blood lead levels were shown to be generally correlated in taxi drivers and in other adult groups, some occupationally exposed to automobile exhaust (15); air exposure levels were measured by personal monitors.

--- Elevated blood lead levels were found in children attending school in areas with higher air lead levels in contrast with blood lead levels in school children exposed to lower air levels. The differences in air levels in this study were, however, relatively small (16); for this reason, dust-fall lead may also have been incriminated, especially as peeling paint was not considered to be a problem in the area cited. These findings were confirmed in additional studies of 230 rural children and 272 children from an urban ghetto (17). Approximately 25% of the urban children had abnormal blood lead levels, greater than 40 μg/100g, compared to less than 10% of rural children. Evidence of accessible hazards from leaded paint could only be found in 60% of urban children with elevated blood levels.

Elevated levels of urinary coproporphyrins have been reported in school children aged 5 to 7 in the vicinity of smelting plants and a pewter factory in the USSR (18). Children exposed to ambient air lead levels of 2.5 $\mu g/m^3$ and 1 $\mu g/m^3$ had 8 hour urinary excretion levels of 10.5 μg and 8.2 μg, respectively, in contrast with 6.5 μg excretion levels in control children exposed to air lead levels below 0.01 $\mu g/m^3$. Elevated blood levels in children residing near a smelter in El Paso, Texas, have also been recently described (8). Approximately 90% of children from 1 to 5 years had blood lead levels over 40 μg/100g. The role of dust fall was suggested by street dust lead levels ranging from 4,000 to 5,000 μg/g; while airborne lead was highly elevated near the plant, 100 to 300 $\mu g/m^3$, approximately 75% of the lead was considered non-respirable. More recently, there have been preliminary reports of elevated body burdens in children living in downtown Toronto close to lead smelting plants (19, 20). Ambient air lead levels of 5.5 $\mu g/m^3$, ranging up to 18 $\mu g/m^3$, have been reported at Bruce Public School, approximately 100 yards from the Canada Metals smelting plant in Toronto. Of 600 children in this school, 49 had blood lead levels greater than 40 μg/100g. Fresh window dust levels in houses within 100 yards of the plant of up to 5% lead have also been reported; high blood lead levels have also been reported in adult residents. There have been several additional reports of increased lead body burdens in children and adults residing in the vicinity of lead smelting plants (21-24).

Studies of human volunteers continuously exposed to approximately 3 $\mu g/m^3$ of airborne lead in controlled chambers demonstrated small but significant increases in blood lead levels (25). These increased blood lead levels were comparable to those found in women living near well travelled roads in the "roadway study" (12).

— The results of both roadway studies (12, 14) and the controlled chamber study (25), in general, confirm the implications of the Goldsmith-Hexter regression equation (26) relating changes in average blood lead levels of various groups to their exposure to atmospheric lead. While there are various problems relating to the quantitative use of this regression equation, including statistical methodology, the composite nature of the data used and the estimated rather than measured air lead exposures, the equation is generally considered to demonstrate that average blood lead levels in population groups will increase as a function of increased air exposure levels at any level of air lead (1).

— Occupational exposure to inorganic lead occurs predominantly by inhalation of dusts and fumes. Frank acute and chronic lead poisoning are well recognized following occupational expoare to lead. There has, however, been relatively little consideration of more subtle long term effects following exposure to permissible levels of lead in the 150-200 $\mu g/m^3$ range. There is currently no reporting system in the U.S. whereby the prevalence of occupational lead poisoning can be recognized and documented. In a recent NIOSH criteria document on occupational exposure to inorganic lead, it was recommended that occupational records should be maintained for "at least five years after the last exposure to inorganic lead" (7). However, chronic effects may manifest up to one or two decades subsequent to exposure. Excess deaths from cerebrovascular accidents and from chronic nephritis have been reported in retired British battery workers, and in plumbers and painters (27, 28). There have, however, been no adequate published U.S. epidemiological studies in workers occupationally exposed for more than two decades. Recent unpublished U.S. studies have, however, indicated an approximate 10% incidence of hypertension in chronically exposed lead workers (29). Additionally, disturbance in and personality and intelligence have been reported in lead workers in the absence of overt lead poisoning (30). The manufacturer of alkyl lead antiknocks, and the blending and handling of leaded gasoline represent further important sources of occupational exposure and poisoning, and this should be recognized as a significant negative "trade-off" in policy options based on the continued use of leaded gasoline.

2. Ingestion

Ingestion of lead paint and plaster chips, by infants and young children, in the common behavior anomaly of pica, is well established as a cause of increased lead body burdens and acute and chronic lead poisoning. Although peeling lead paint in old homes has been clearly incriminated in many cases of severe lead poisoning in children, the sources of exposure in many cases of elevated blood levels or poisoning is undetermined (31, 32). Additionally, the obvious lead paint hazard has been inappropriately used as an argument to preclude the further possibility of increased lead burdens and poisoning resulting from ingestion of street dust and soil contaminated with lead from automobile emissions.

The 1972 NAS report (10) states unequivocally:

> "... the daily ingestion by a child weighing 10 kg of 0.41 g of street dust with a lead content of 2,000 μg/g would result ultimately in a blood lead concentration compatible with clinical lead poisoning, even without allowing for additional lead acquired by inhalation from normal dietary sources or from coincident ingestion of leaded paint. Likewise, approximately 44 mg of street dust daily (a fraction of a teaspoon) would suffice to increase the daily lead accumulation from that associated with a blood lead content of 20 μg/100g of whole blood to that associated with 40 μg/100 g of whole blood."

There are well established data indicating that lead fall-out from particulate automobile emissions results in high lead levels in urban street dust, soil in gardens and parks (see Section 1 C.4). These data clearly demonstrate markedly increasing dust levels with proximity to highways and with commercial, as opposed to suburban and residential, areas. Additional supportive evidence for the importance of lead fall-out includes the following:

— Average lead levels in front yards of urban houses are 200 to 300% in excess of levels in back yards located further from densely travelled highways (33).

— Levels of house dust lead in middle class urban homes, in some cases exceeding 600 μg/g, are approximately double those of middle class suburban homes (33); these levels are much greater than those considered safe in paint by the FDA (34). Recent surveys of dust in Boston homes have revealed elevated lead levels, predominantly in the range of 1,000 to 2000 μg/g, often in homes built after 1950 where the possibility of lead paint can be excluded (35). The lead content of house and hand dust and mean blood levels are higher for inner city than for suburban children (36).

Quite apart from pica, in which dangers from dirt and dust ingestion are much higher, hand-to-mouth and oral activity is marked and normal in young children. Calculations, based on demonstrated mean dust values of 11 mg/hand in Hartford infants, indicate that minimally 110 mg of dust could be ingested daily merely by sucking on dirty fingers (37). With contaminated dust this would result in ingestion of levels in excess of the recommended USPHS daily permissible intake (DPI) of 300 μg (38); some investigators consider this DPI to be excessive (39, 40).

— Concentrations of 1,750 μg/g lead in dust on window frames near well travelled highways have been recorded in various European cities (41).

— Data from New York City indicate that only 50% of children with blood lead levels between 35 and 44 μg/100 g can be associated with obvious peeling lead paint problems and that 20% of these children lived in homes where no peeling paint could be found (42).

— Long term studies following exposure of a population group to elevated levels of lead in drinking water revealed an increased incidence of chronic nephritis in the absence of other recognizable signs of plumbism in the period of exposure (43).

— Recent concerns have been expressed concerning the contamination of shell fish by lead fall-out, which subsequently reaches ground waters through periodic rainstorm street washings (1); improper disposal of leaded petroleum products and wastes may also be incriminated.

B. <u>Predisposing Factors to Increase Lead Body Burdens</u>

Infants and young children living in certain urban areas may be at high risk from lead exposure due to inhalation of airborne lead, and ingestion of lead

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contaminated dust, in addition to the well recognized problem of ingestion of lead paint.

There are a variety of factors which additionally may predispose these high risk children to the effects of increased lead intake. These children generally belong to low socioeconomic groups and hence may suffer from dietary calcium and iron deficiencies which are known to increase lead absorption and also to potentiate the toxic effects of lead in humans and in experimental animals (16, 44, 45). Additional possible predisposing factors to lead toxicity include sickle call anemia and glucose-g-phosphate dehydrogenase deficiency, both genetic anomalies relatively common in black people.

C. Potential Toxic Effects from Intake of Lead Particulate Emissions

1. Absorption

Based on balance studies in adult men, the net absorption of lead from the alimentary tract has been estimated to be 10% (46); more recent sutdies suggest that young children, contrastingly, absorb as much as 50% of their oral intake (40). While the time taken to achieve a steady state following a substantially increased lead intake is unknown in adults (10), equilibration certainly does not occur during fetal life when cumulative upteke occurs in the whole body and particularly in bones (47). Absorption from the alimentary trect is increased by iron and calcium deficiency (44, 45), both common in young children in ghetto populations. Additionally, it is very likely that absorption of lead from finely particulate leaded dust is much greater than from reletively large flakee or chips of leaded paint; this, however, does not eppear to have been studied experimentelly. In this connection, it should be pointad out that the presence of paint flakes, as determined radiologically, in the alimentary tract of young children with reletively elevated levels of blood lead or with lead poisoning does not neceseerily contra-indicate the fact that poisoning may, at least in part, be due to ingeetion of leaded dust fall-out, particular when lead concentration in dust can reach as high as 0.5%.

The pulmonary deposition of inhaled particulates will depend on their size. Large particuletes, greeter than 2μ, tend to be trepped out in the upper respiretory tract and cleared by muco-ciliary mechanisms, and particulerly in the case of young children, swallowed rether than expectoretad. A bigh percentege of emitted exhaust particulates fall in the respirable range and tend to be deposited in tbe lung, as their average MMED is 0.25 μ (see Section 1 C.5). Various crude estimates of tbe deposition of inhaled particuletes from ambient urban eir have been made; thesa suggest an average retention of 37% (10). While various studies (sea Section II A.1) have demonstreted e general correletion betwean respiretory exposure and blood lead levels, however the axtent of retention and lead absorption from deposited particuletee has not been adequately invaatigated. The consensua of opinion indicates that, in the particle aize range found in ambient air, lead deposited in the respiretory tract remains there (10) and thus will be ebsorbed. As stated in tbe NAS report.

> "For all prectical purpoeas all the lead deposited in the lungs seems to be reteined".(10).

2. Blood Lead Levels

According to Goldsmitb's deta (26), tbe composite urban U.S. populetion has a mean blood lead of 21 μg/100g. Heelthy adults usually do not exhibit obvious symptoms until blood level reach 80 μg/100g. However, most authorities, including those on the staff of leading manufecturers of lead additives, agree that 40 μg/100g is the upper acceptable blood levels for adults in tbe general population (1); there is elso some consensus thet upper acceptable blood levels for pregnant women, for cord blood and for neonates are 30 μg/100g, and for young children ere in the region of 35 μg/100g. The possibility exists thet these levels ere excessively bigh. A recent survey on 162 children in Nurenberg bas demonstreted median blood lead concentrations of 3.3 ± 2.6 μg/100g for children eged 0 to 1 yeers, 3.7 ± 5.4 μg/100g for children aged 1 to 2 yeers, 8.2 ± 5.6 μg/100g for children eged 2 to 3 years and 8.3 ± 4.4 μg/100g for children aged 3 to 4 years (48). The implications of this study, if confirmed, would necessitate a drastic reduction in currently considered "normal" ranges in blood lead values.

Recent surveys in a wide range of U.S. cities have demonstrated an "epidemic" occurrence of excessive lead exposure in that 20% of one to six year old children tested had blood levels greater than 40 μg/100g (49); these data do not allow definition of the relative roles of airborne and dust-fall lead and of leaded paint.

It must, however, be stressed that blood lead levels only reflect recent exposure to lead, and generally give little or no indication of the total body burden of lead or of past exposures. Clinical evidence of lead poisoning can thus occur in children with normal or near normal lead levels in the range of 40 to 50 μg/100g (1, 47, 50, 51). Bone biopsies, while impractical, give a much more reliable indication of total lead body burdens. Bone lead is biologically available and can be mobilized under a variety of metabolic conditions and by chelation therapy (10). Lead workers removed several years from exposure still have high levels of blood porphyrins, presumably because of the slow release of accumulated lead reserves particularly from bone storage depots (52). Recently, circumpulpal dentine lead levels have been used to provide a more realistic measure of body burdens (53); using this technique, a group of white school children living in generally good housing, but with high levels of household dust, 3000 to 4000 ppm due to proximity to a lead processor, were found to have marked elevation in tooth lead levels. Additionally, lead levels in teeth from seventeen Icelandic children were shown to be approximately half of those of 20 suburban Boston children ($p < 0.005$) (54).

3. "Low Level" Toxic Effects

There has been recent growing recognition of the potential significance of "low level" toxic effects of lead in contrast with the well-recognized clinical pictures of acute and chronic lead poisoning.

--- Delta aminolevulinic acid dehydrase (ALAD), an enzyme involved in hemoglobin synthesis, is inhibited by low levels of lead (55). Inhibition of this enzyme has been demonstrated in brain, kidney and liver of rats (55); enzyme levels in blood and brain correlate well (56). An inverse linear relation between ALAD activity and blood lead has been demonstrated over a concentration range of 5 to 95 μg/100 g (55). This suggests that ALAD inhibition in blood of young children occurring in the 20 to 40 μg/100g range may be associated with biochemical abnormalities in the brain (1). Experiments by J.C. Calandra (cited in the September 1972 draft of Ref. 1, but omitted in the final draft) confirmed inhibition of ALAD in vivo by blood lead levels as low as 22 μg/100g.

--- There is particular and growing interest in the possibility that low levels of lead can produce behavioral and learning disorders in children. Convulsions, encephalopathy, irreversible brain damage and subsequent mental retardation are well recognized sequelae of lead poisoning in children. As frank lead encephalopathy produces such severe and permanent neurological damage, the production of more subtle effects from lesser degrees of exposure is only to be anticipated. Additionally, mental retardation has been reported in follow-up studies of children with asymptomatic lead poisoning (57); improvement in behavior and language ability has also been reported following treatment of asymptomatic children with excessive lead exposure (58). These concerns have been recently emphasized by the findings of disturbances in personality and intelligence in lead workers in the absence of overt lead poisoning (30). There are now scattered reports that exposure to relatively low levels of lead, in the absence of acute poisoning, can produce psychological deficits and behavior anomalies, including hyperkinesis, intelligence impairment and learning disorders (49, 59-61). The hyperactive children were observed to have higher blood lead levels, besides a 2-fold average increase in urinary lead excretion, following chelation therapy, than found in partially matched control groups (59); urinary lead excretions were abnormally elevated in 60% of the hyperkinetic children as opposed to in 21% of control groups. Additionally, a history of lead exposure was claimed to be common in the hyperkinetic children. The NAS report (10) acknowledges the possible effect of low lead levels in inducing hyperkinetic and behavior anomalies:

> "The subtle effects on behavior of low lead exposure on long duration without prior acute exposure may be manifest in two types of disorder; the dulling of mentation and chronic hyperkinesis. No information is available regarding the possibility of cause and effect".

--- There is also some experimental confirmation of the clinical findings of hyperkinesis due to lead exposure. A 3-fold increase in activity levels of infant and young mice exposed to lead in maternal milk has been demonstrated compared to matched controls (62). Exposure of rodents for two months to air lead levels of 11 $\mu g/m^3$ produced disturbances in conditioned reflexes and also histopathological changes in the brain (63); some of these effects may be partly due to the grooming of lead-contaminated fur. Electro-encephalographic studies in rats exposed to lead acetate have demonstrated impaired neural control (64). The results of these studies may be related to the inhibitory effects of low levels of lead on rat brain ALAD (55) and the inhibitory effect of lead on rat brain dopamine (65). Additionally, impaired learning, as measured by non-spatial visual discrimination tests, has been reported in ten to fifteen month-old sheep following exposure in utero to maternal blood lead levels of 34 $\mu g/100$ ml (66). Hyperactivity and insomnia were observed in infant monkeys with blood lead levels below 100 $\mu g/100$ ml (67);

abnormal social interactions persisted in monkeys recovering from higher blood lead levels.

--- Chromosomal anomalies have been reported in peripheral lymphocytes of occupationally exposed and lead poisoned men (10, 68) and in mice (69). Anomalies have also been reported in community populations in the vicinity of a lead smelting plant (70). While no genetic studies on low levels of lead have been published, mutagenic effects could be anticipated in view of the non-threshold nature of such genetic damage.

--- Excess lead exposure of pregnant women results in neurologically damaged infants with intra-uterine and post-natal growth retardation (10, 71).

--- A wide range of experimental studies have demonstrated that oral or parenteral administration of lead salts induces chronic nephropathy and renal adenomas and adenocarcinomas in rats (72, 73) and in mice (74).

--- There are some indications that lead potentiates viral disease and inhibits the antiviral activity of interferon inducers (75). Additionally, large doses of lead potentiate bacterial infections (76), increase sensitivity to bacterial endotoxins (77) and inhibit specific immunological responses (78).

D. Conclusions

While none of the above cited lines of evidence is alone conclusive evidence of sub-clinical brain damage and other sub-toxic effects from low levels of lead, in concert they arouse a strong index of suspicion which adequately justifies public health policies designed to reduce lead exposures. Moreover, these findings clearly indicate that there is virtually no margin of safety between lead exposure levels and potential adverse effects in urban community situations, quite apart from occupational exposure where permissible levels, TLV for lead is currently 150 ug/m^3, are already well above the toxic range. This is in striking contrast to standard toxicological practice where permissible exposure levels are minimally based on 100-fold safety margins.

Over and above the question of safety margins, it must be stressed that the standard and conventional method for detecting and measuring the effects of lead exposure by blood analysis may well be misleading. While blood levels reflect relatively accurately recent exposures to lead, they do not reflect total body burdens and thus ignore the cumulative effect of lead toxicity, the cumulative storage of lead and its potential availability following mobilization, particularly from bone depots.

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III. DESIGN, PERFORMANCE AND COST OF LEAD TRAPS

A variety of lead traps systems have been recently developed which are designed to remove particulate lead from the exhaust of cars with conventional internal combustion engines operating on conventional leaded gasoline. These trap systems would allow continued use of leaded gasoline, as an alternative to removal of all or part of the lead with some attendant fuel penalties, while controlling lead particulate emissions. Some of these systems have been designed for retro-fit purposes, to replace worn mufflers on in-use cars, while others have been designed for installation on new cars, other than those with lead-intolerant gaseous emissions control systems. It should be appreciated that, in contrast to the intensive world-wide efforts that have been expended on development of gaseous emission control systems, R&D on lead trap technology has been on a relatively small scale and restricted to a small segment of industry, notably Du Pont Co. and, to a lesser extent Ethyl Co.

The Du Pont particulate trap is the most highly developed and tested of all known systems. With the additional exceptions of the Ethyl and Texaco-Octel systems, no other traps have yet progressed beyond the stage of limited laboratory testing. All traps, with the exception of the Cooper Unions Molten Salt device and the IIT Research Institute thermal packed bed, depend on inertial separation with preceding cooling, coagulation and/or agglomeration to facilitate lead particle separation.

A. Du Pont Traps

The data on which the following discussion is based have been published by Du Pont in both summary and extended form (1, 2).

1. Design

Du Pont muffler traps have been designed to retro-fit in-use cars. Additionally, the design principles have been extended to produce long-life traps for installation on new cars with lead-tolerant gaseous emission control systems. The basic principle depends on the cooling of exhaust gas to initiate particulate lead formation and agglomeration in the exhaust trap system, followed by the separation and collection of the exhaust particulates in a cyclone trap. "Type III" traps are relatively simple, and without modification can be used to replace mufflers on in-use cars. Exhaust gas enters one end of the muffler trap and is efficiently agglomerated by flowing over a bed of high surface area alumina pellets, from which it passes to two inertial cyclone separators and thence into a plenum collection chamber designed to prevent particle re-entrainment. While less work has been done on the use of traps with alternate power systems designed for leaded fuel, such as stratified charge, it appears that such traps can be as effective as with conventional internal combustion systems.

More complex and sophisticated traps, suitable only for installation on new cars by the manufacturer are exemplified by "Trap System B". The standard exhaust pipe is replaced by a dual exhaust system of fluted pipes lined internally with wire mesh to promote additional cooling and agglomeration. The pipes are exhausted into a mesh-filled common box from which they pass to two cyclone separators, one in each rear fender well. A modified version of Trap B has been combined with exhaust manifold reactors and air injection, to oxidize hydrocarbon and carbon monoxide, and with exhaust gas recirculation to control NO_x emissions in order to produce a "Total Emissions Control Systems" (TECS) (3). TECS are designed to meet 1975 and 1976 U.S. emission standards, but are still in developmental stages. Considerable developmental work has also been done on total final filters mounted behind traps; greater than 95% retention can be achieved, although problems of back pressure have not been resolved. The durability of construction materials and the size of collection chambers can be modified to produce a trap-life extending up to 100,000 miles.

2. <u>Performance with Relation to Lead Trapping</u>

Evaluation of the qualitative and quantitative role of traps in reducing lead emissions requires comparative characterization of exhaust particulate matter in trapped and non-trapped cars. Some exhaust particulates are generated in the combustion chamber and are agglomerated in the exhaust system prior to emission. Other emissions originate from re-entrainment of particulates deposited throughout the exhaust system. Thus, the nature and quantity of emissions at any one time is highly variable and depends on precise operating conditions.

Most studies on particulate emissions have focused on lead rather than on other particulates which are less well characterized. Early studies on cars operating on chassis dynamometers (4) have established that lead emission rates are directly dependent on fuel lead concentrations, speed, load and accumulated mileage. Much of the burned lead is retained in the engine oil and the exhaust systems under normal operating conditions and this is partly re-entrained during high speed and load conditions, resulting in 10 to 20-fold increases in lead emission rates; it was also noted that the ratio of coarse to fine particles increases with increasing speed and load conditions. More accurate particulate lead emission rates are determined using a total exhaust filter on cars operating on a programmed chassis dynamometer (PCD), in accordance with the Federal Mileage Accumulated Schedule. Size distribution analyses can be accurately performed, on cars operating on a PCD, based on the constant volume proportional sampling principle and on isokinetic sampling, using an Andersen Sampler and a Monsanto Impactor for particles in the range of 0.3 to 9 μ and an absolute filter downstream of each impactor for particles less than 0.3 μ. The most recent attempts to correlate emissions and atmospheric effects have been conducted in "controlled atmospheres" in a sealed turnpike tunnel (5). The effects of leaded fuels on total perticuleta emissions, soiling, reduction in light visibility and atmospheric lead levels have been studied in restricted teets.

Using these techniques, it was confirmed that the total lead particulate emissions were highly veriable, depending on opereting conditions, and ranged from approximately 0.05 to 0.4 g/mile (2); particle size distributions suggest e linear positive reletion between size and eccumulated mileage (5). Io one schedule, et an averege of 5,000 mileage, tha percentages of emitted lead greeter than 9 μ and less than 0.3 μ wera 27% and 30%, respectively; tha corresponding valoes at 28,000 miles wera 57% and 11%, respectively. These proportional changes witb mileage are peralleled by absolute changes.

Particulata emissions from unleaded fuels ara largely black, carbonaceous, of reletively low density and thus of graetar volume per unit mass than is tha case with leaded particuletes. The unleaded perticulatas thus have a proportionately greatsr effect on visibility and soiling (5). Total particulate emissions with leaded fuel are relatively insensitive to choking which markedly increases unleaded emissions. The contribotion of lead emissions to total etmospheric particulata loadings is reletively low and is estimated to be 0.5 to 1.5% in suburban areas, 1.4% downtown and 5 to 8% on bighways.

Reproducible quantitetive assessmeot of performance efficiency of lead trape is methodologically complex. Emissions must be compared by different laboratorias over e wide range of opereting conditions and for extended pariods in a large oumber of production besides prototype vehicles, using standard and acceptabla procedures for charactarizing exhaust particulates (2). These requirements eppear to have beeo largely met in the publisbed litereture on Du Pont treps (1, 2), which appears to support the following conclusions:

— Lead traps redoce total lead emissions from production cars operating on commercial leaded gasoline, from 82 to 91%, as measured in long term laboretory tests;

lead emissions in current full-size vehicles range from 0.12 to 0.15 g/mile (6). These results are confirmed by more recent, but limited, feasibility field tests in San Francisco. Traps can thus reduce leaded particulate emissions from full-sized vehicles to less than 0.02 g/mile, thus meeting the previously recommended 1975 EPA particulate emission standards of 0.1 g/mile and meeting the proposed 1980 goal of 0.03 g/mile; emissions from smaller cars would be proportionately lower relative to fuel consumption.

--- Lead traps reduce large size particles by more than 85% and airborne particles, less than 0.3 μ, by more than 68%, as measured by laboratory tests; further, they reduce airborne particles by 64 to 84%, as measured in turnpike tunnel road tests(5). As determined by various investigators (6), the MMED for atmospheric lead particulates is 0.25 μ. Most recent estimates indicate that the size distribution of urban atmospheric lead ranges from 0.2 to 1.43 μ (see Section 1 C5). Size distribution analyses of in-use cars indicate that approximately 20% of emissions consist of particles less than 0.3 μ (6). Thus, high trapping efficiencies, greater than 68%, for these small particulate emissions are particularly important in reducing levels of airborne lead.

--- Lead traps incorporated in TECS reduced total emissions by 85% and airborne lead by 71% in tunnel tests. While such systems have not yet demonstrated 50,000 mile durability, neither, according to manufacturers, have the catalytic systems planned for 1975 and 1976.

--- The performance of traps is relatively stable and is not materially altered by variations in the driving cycle or operating conditions, nor is it decreased by accumulated mileage, nor is it dependent on owner maintenance. Temporary reductions in efficiency may result from "upsets", such as burned valves or over-rich mixtures. In contrast, lead emissions are erratic and increase with mileage in cars with standard exhaust systems, due to the continuous accumulation and re-entrainment of deposits from the interior of the muffler and exhaust pipe and from the engine.

--- More limited independent tests by three other laboratories (Dow, Ethyl and Esso) on cars with Type III traps closely confirmed the results of the Du Pont tests in relation to g/mile emissions.

--- It is demonstrated that the use of traps under defined conditions will result in a similar reduction in lead emissions, to less than 65% by the summer of 1977, as would be effected by the proposed EPA 1972 schedule (14). It appears that likely the use of traps on both in-use and new vehicles will result in a more rapid reduction in lead emissions than that achievable by the December 6, 1973 "phase-out" regulations (18).

3. Other Aspects of Performance

The Du Pont literature (1, 2) states that the durability of Type III retro-fit traps is excellent and only little attrition is observed following 50,000 miles operation, during which time back pressure did not increase. Fuel economy and acceleration of trap-equipped cars is stated to be the same as that of cars with conventional exhaust systems. There are no published data on attenuation of exhaust engine noise.

In addition to reducing lead emissions, traps significantly reduce a wide range of other non-regulated particulate emissions. The efficiency of removal of unleaded fuel particulates, which have a relatively high volume but low density, is likely to be lower than for leaded particulates (6). It is generally recognized that use of lead increases the total particulate emissions relative to unleaded fuels. The extent of this increase reflects measurement technology; it is claimed to be as high as 10-fold (7), and as low as 2-fold (8, 9). These particulates consist of complex oxyhalides as a core around which solid or liquid organic combustion products condense. The organics include polynuclear aromatic hydrocarbons, phenols and aldehydes; their concentrations in emissions do not appear to be altered by the presence of lead in gasoline. In particular, advanced trap systems, such as Type B, also markedly reduce emissions of semi-solid particulates such as "tars" and also higher boiling point polynuclear aromatic, such as benzo(a)pyrene (7, 10); further reduction in benzo(a)-pyrene emissions can be achieved using TECS.

4. Cost To The Consumer

Firm cost estimates for traps, as for many other projected emission control devices, are not available because many of these systems are still undergoing active R&D and testing. However, the cost estimates by Du Pont and two independent manufacturers for manufacturing costs of retro-fit muffler lead traps is approximately $9 in contrast to standard muffler costs of $4.50 (1, 2). Based on current commercial mark-up practice, the jobber and garage selling prices to motorists are projected at approximately $35 and $41, respectively, approximately double the corresponding current selling price of mufflers, $18. Minimally, the retro-fit traps would have a life of at least as many miles as the mufflers they replace, greater than 37,000 miles. Traps for new cars are of a larger volume than retro-fit traps; this, together with increased construction durability is expected to result in life-time use, approximately 85,000 miles (2). In contrast to long-life current production mufflers, incremental consumer costs of $29 for long-life lead traps are anticipated. These incremental costs of lead traps must be contrasted with incremental consumer costs due to reducing lead in gasoline or using lead-free gasoline. The latter costs have two components — firstly, the fuel economy penalty due to the reduction of compression ratios necessary for operation of new cars on lower octane, and, secondly, and less significantly, the increased costs of low lead and lead-free gasoline. Decreased compression ratios sufficient to reduce octane requirements by one octane number result in a decrease of 1.5% in fuel economy (11); thus, the fuel economy penalty due to operation of 91 RON unleaded gasoline would be as high as 10.6%; other estimates on fuel penalties range from 5.4 to 11.9% (12). Calculations of precise incremental consumer costs are complex, depending on a wide variety of factors. Based on Aerospace Co. data (13), it is claimed that incremental costs will be 0.33¢/gal., rather than EPA estimates of 0.25¢/gal. (14).

Using conservative estimates and ignoring possible penalties due to projected use of gaseous emission control systems, it appears more costly to the consumer to use unleaded or low lead gasoline rather than to use lead traps. Illustratively, incremental costs to the consumer from using life time lead traps and current leaded gasoline, approximately $29, are contrasted, based on all new cars operating for 85,000 miles on unleaded gasoline, with increased gasoline costs of $181 at current rates due to reduced compression ratios and a further $29 due to increased gasoline costs. Thus, energy considerations apart, there may be an incremental cost penalty of approximately $180 from the use of non-leaded gasoline as an alternative to lead traps in the limiting case when all cars are new. An offsetting factor is increased spark plug and exhaust system life in cars using unleaded gasoline (13); however, many trap exhaust systems are being designed for life-long use.

5. Energy Deficit From Stepwise Reduction in Lead Levels in Gasoline

Estimates on the energy deficit due to the use of gasoline with stepwise reduction in lead levels, as opposed to the use of fully leaded gasoline with traps, are complex for a variety of reasons. These include failure to differentiate total energy impact from direct impact on gasoline production, specifically; reliance on assumed typical refinery process data, while in fact no two refineries are the same; and, inclusion in net energy balance calculations an assumed, but unproven, economy from the use of catalyst - equipped cars. It is thus not surprising that energy deficit estimates range widely, from 0.4% crude (1% gasoline) (18)to 15% crude by PPG Industries, Inc.; average refinery estimates are 1% to 1.5% crude (1.5%) to 2.5% gasoline). These estimated energy deficits must be clearly differentiated from additional deficits due to use of lead-free gasoline.

B. Ethyl Co. Particulate Trap

The prototype unit is the anchored vortex cyclone trap, which contains one or more inertial seperation tubes with swirl vanes in the inlet section to provide the vortex flow (15); collection chambers are filled with small squares of expanded metal to minimise particle re-entrainment. These simple traps can be easily retro-fitted, but only reduce total lead emissions by 52% and airborne emissions by 38%. Trap systems based on the latb agglomeration principle, designed for retro-fitting on small foreign cars, have been developed and tested on the Toyota and Fiat and have achieved higher trapping efficiencies than prototype models; these traps produce an 80% and 75% reduction in particles greater than 0.9 μ and less than 0.4 μ, respectively. Developmental tests on a single unit incorporating an alumina mesh bed and an anchored vortex trap, designed for retro-fitting, demonstrate significantly higher trapping efficiency. More advanced units designed for new cars are based on the tangential entry anchored vortex trap as a pre-cleaner or pre-filter for cooling, and agglomeration and separation of agglomerated particles ahead of a final filter system. These units have a very high efficiency and reduce total particulate emissions to as low as 0.007 g/mile, without any increase in back pressure.

C. Texaco-Octel Filters

These filters have been developed through an agreement between Texaco and Octel, using a Texaco patented alumina deposition process (16). The system is based on multiple filters constructed of alumina coated wire mesh. Trapping efficiency is dependent on temperature and on filter volume and on the greater volume of the front than the rear filter. These filters can be retro-fitted in normal exhaust systems and trap approximately 80% of fuel lead and total particulate emissions. With larger size filters for new cars, emissions can be reduced by approximately 90%. Using the alumina filters as pre-filters for Pittsburgh Plate Glass (PPG) fiber glass filters results in a decreased overall lead emissions to less than 4% of fuel lead over a

25,000 mile test; with subsequent mileage, emissions were reduced to less than 1% without significant back pressure affects.

In addition to Octal tests in England, involving more than 1.5 million car miles, confirmatory test programs have been undertaken in France and Germany. It appears that these systems can easily meet the proposed particulate emission standards of 0.03 g/mile and can control lead emissions more economically than by reductions in gasoline lead.

D. <u>EPA Critique of Lead Traps</u>

The January 10, 1973 EPA regulations (17) require the general availability in 1974 of an unleaded and phosphorus-free gasoline of at least 91 RON for 1975 model cars; the 12/6/73 regs. require stepwise reduction of lead in regular and premium grade gasoline to a maximum total pool average of 0.5 g/gl. by January 1, 1979 (18).

The requirement for unleaded gasoline is based on the projected need for lead-intolerant catalytic oxidant emission control systems for 1975 cars. The requirement for stepwise reduction in gasoline lead is based on the appreciation of potential public health hazards due to lead emissions. Both requirements are calculated to yield a 65% reduction in lead emissions by 1979.

EPA considered lead traps as an alternative to the stepwise reduction of lead in gasoline for lead-tolerant vehicles, but rejected this on the grounds, which do not appear to have been adequately documented, that they were neither technologically nor economically feasible (14). EPA also rejected the possibility that lead-tolerant catalyst emission control systems could be developed for 1975 to 1976 cars, a position widely supported by industry. The EPA objections to lead traps are examined in detail in a Du Pont publication (2), where it is claimed, on the basis of detailed supporting data, that these objections appear either factually incorrect or have been invalidated by recent new developments. In conflict with EPA conclusions, emission control systems, such as TECS, capable of meeting 1976 standards, are being actively developed and could well subsequently replace lead-intolerant catalysts. Again, industry data indicate that reproducible and reliable comparative determinations of particle mass and size distributions have been made by independent laboratories on cars with traps and with conventional exhaust systems. While EPA statements that traps are less efficient for airborne than for large particles appear correct in principle, however, cooling and agglomerating systems upstream of the cyclone have been developed to convert small into large particles. Additionally, independent tests have confirmed removal by traps of more than 64% of airborne particles. Thus, lead traps installed both on in-use and new cars would decrease the total lead emissions more rapidly than would be the case with the "phase-out" regulations.

With regard to comparative costs of traps versus phased lead reductions in in-use cars, it appears that EPA may have over-estimated the cost of lead traps, by assuming high consumer costs rather than accepting informal cost estimates of muffler manufacturers which indicate an approximate 2-fold incremental cost. This error appears due to the equation of costs of replacing a complete exhaust system with the lower costs of muffler replacement. Additional sources of error for the cost of removing lead from gasoline appear to be due to estimates based on increased refinery costs, rather than on increased costs to the consumer. Du Pont presents data indicating that the cost of removal of lead from gasoline for in-use cars, $17 to $59, is at least as high, if not higher, than the cost of retro-fitted traps, maximally $19 increment over muffler costs (2). Du Pont claims that EPA similarly over-estimated trap costs on new cars; EPA estimates of $65 for traps on new cars are based on installation of complete exhaust systems. Du Pont data indicate that the maximum incremental cost to the consumer will be approximately $29 for traps designed for life time use. Again according to Du Pont, EPA under-estimated the fuel penalty and increased consumer costs from unleaded gasoline on new cars, which will probably range from $200 to $270 over the life time of the car.

E. Recycling Lead From Traps

Use of alkyl lead fuel additives, at a rate of approximately 300,000 tons annually, represents a depletion of an important natural resource. The evaluation and significance of such depletion, and hence of the need for recycling, should reflect considerations including the following:

1. Lead as a Non-Renewable Resource

The earth's lead resources are currently being mined at an approximate annual rate of 2.2×10^9kg (19). Even optimistic approaches suggest that lead demand may exceed estimated reserves within the next few decades (20).

2. Recent Patterns in Lead Consumption

Annual US lead consumption has approximately doubled over the last three decades — from approximately 780,000 tons in 1940 to 1,300,000 tons in 1968 (19); during this period, there has been a major absolute and proportional annual increase in consumption of lead fuel additives from 50,000 tons in 1940 (6%) to 260,000 tons (20%) in 1968 (22). Recycling from various sources other than lead additives accounts for more than one-third of lead used (21).

3. Lead Emissions from Gasoline

While there is little doubt that combustion of leaded gasoline represents a major preponderant source of lead emissions, estimates (14, 23) that gasoline was responsible for approximately 98% of the 1968 emissions of 184,000 tons are questionable. These estimates are based on an incomplete inventory, ignoring emissions from sources such as municipal incinerators, weathering and combustion of lead products and external venting from a wide range of occupational sources. However, possible over-estimates of the proportionate contribution of emissions from gasoline combustion may well be partially compensated by unacknowledged emissions from evaporative losses of lead alkyls from emissions of unpyrolysed lead alkyls in exhaust gasoline and from improper disposal of used engine oil (see Section 1B); lead alkyls are rapidly degraded in air to inorganic lead.

4. Recycling Technology

Current lead trap technology has demonstrated that such systems are capable of reducing lead particulate emissions by 80% or more and that such traps can contain over 4,000 gms of lead or over 6,000 gms of lead compounds. Assuming an average lead emission rate of 0.1 gms per mile, 60% of the lead emitted of the lead burned, and an 80% trapping efficiency, then the net lead compounds which would be contained by a typical cyclone trap for over 50,000 miles would be approximately 7,500 gms (24).

The technical feasibility of recycling lead from Du Pont traps has been well established (8). Traps are as easy to detach from in-use or scrapped cars as are conventional muffler systems. With appropriate economic incentives, the traps could be segregated and shipped to a central processing location. The unit can be shredded and the powdered lead salts separated physically from the collection chamber, stainless steel wire mesh or alumina pellets. The lead salts and deposits could then be smelted to allow a high degree of recovery of lead, bromine and chlorine. Crude lead salt sludge can be processed together with alumina by secondary lead smelters. The economics of the process have not yet been developed by any of the lead trap manufacturers, but will reflect logistic considerations including collection and shipping of spent traps from junk yards or muffler installers and also the market price for lead, bromine and chlorine. It is, however, unlikely that the need for lead alone will be sufficiently critical to stimulate recycling from traps in the near future (8, 9). One additional factor that may encourage recycling is the consideration that the lead content in traps would be too high for conventional steel scrap smelting and might thus pose a solid waste disposal problem.

F. Reduction of Lead Levels in Gasoline as an Alternative to Lead Traps

1. Reduction of Lead Levels in Gasoline

While the availability of lead-free gasoline, less than 0.05 g/gal., is regulated for model 1975 cars using lead-intolerant oxidant catalytic converters leaded gasoline will still be needed for in-use cars and for cars with alternate power systems capable of meeting 1975 to 1976 emission standards without lead-intolerant systems. EPA recently promulgated regulations on a stepwise reduction of lead concentrations in gasoline to 0.5 g/gal. by January 1, 1979.

Based on Bonner and Moore's data (25), EPA has calculated that requirements for an unleaded grade of gasoline and the then proposed lead reduction would require an additional investment of $1.8 billion prior to 1980. Maintenance of present octane ratings of leaded gasoline would necessitate use of approximately 6% more crude oil in the absence of lead (24). Anticipated energy deficits due to the stepwise reduction of lead in gasoline range from EPA estimates of 0.4% crude (18) to average refinery estimates of 1% to 1.5% crude (1.5% to 2.5% gasoline). Total deficits, from regulations requiring lead-free gasoline (17) and from regulations requiring stepwise reduction of lead in gasoline (18), are estimated to be in the region of 1.5% to 2% crude or approximately 3% loss in total gasoline (24).

Lowering compression ratios to allow use of low octane fuel, as effected for domestic vehicles since 1971, has increased gasoline consumption by about 10% with an attendant increase in crude oil requirements. However, these incremental costs are partially compensated by the fact that unleaded gasoline essentially doubles exhaust system life and increases spark plug life by approximately 50% (13). The basis for the requirement of the unleaded grade is its compatibility with oxidant catalysts and dual oxidation-catalytic systems which are scheduled for use in 1975 and 1976, respectively. Apart from problems of non-regulated emissions, particularly of sulphates which can probably be controlled by desulfurization with attendant costs, and of platinum and palladium, there are unresolved questions as to the durability, performance and maintenance of the catalytic converters. The impact of these negative "trade-offs" is strengthened by the fact that use of converters may discourage more cost-effective methods of decreasing lead emissions. However, given satisfactory performance of converters, their use, at least on an interim basis, will achieve the objectives of the Clean Air Act, allowing development and introduction of efficient alternate power systems less dependent on combustion ratios.

The impact of lead reduction regulations in the total gasoline pool would be partly a function of time schedules. A reduction schedule to approximately 1 g/gal. over three years would minimize impacts and allow orderly reshifting of refinery operations. A sudden removal of lead would, however, produce dramatic fuel shortages, in terms of an overall reduction of available gasoline supplies by as much as 10%. Octane ratings could be maintained by addition of increased levels of aromatics, recognizing that this will require increased amounts of crude oil processes to meet gasoline demands.

While it is recognized that there is a linear relationship between fuel aromatics and exhaust polynuclear aromatic hydrocarbon emissions, these could be limited by emission control devices. While increased fuel aromatics result in increased fuel polynuclears, the increases were smaller, both relatively and absolutely, with emission control systems (7); currently, automobile emissions account for less than 2% of total polynuclear emissions. Increased fuel aromatics also result in increased emissions of phenols and aromatics, but not of aliphatics and aldehydes (7, 10); again, these are controllable by emission devices. The exhaust photochemical reactivity following a 10% aromatic increase in gasoline appears insignificant (10); any possible increases in reactive aromatic emissions would be offset by decreased olefin emissions due to complementary reduction in olefin and paraffin content of the modified gasoline.

2. Use of Alternative Anti-Knocks

The use of alternative anti-knock compounds, particularly methyl cyclopentadienyl manganese tricarbonyl (7, 26, 27) is now receiving further consideration as an alternative, rather than as a supplemental, anti-knock. While manganese is less cost-effective than lead, it can be used either in lead-free fuel or as a lead supplement. When used alone as a primary anti-knock, recommended levels, as manganese, are 0.05 to 0.125 g/gal. (28). Concentrations of 0.125 g/gal. manganese or of 0.5 g/gal. lead produce equivalent octane rating increases of 2 RON. The area of "cost-balance" for manganese-lead combinations occurs when manganese concentrations of approximately 0.1 g /gal. are used with high lead concentrations, more than 2 g/gal.

It appears that manganese particulates are principally emitted as Mn_3O_4 and that the percentage emitted versus the percentage burned and the size distribution of manganese particulates are similar to corresponding values for lead anti-knocks (28). Thus, it may be anticipated that trap technology will be as effective for manganese as for lead.

Effects of manganese on engine durability are complex (27, 28). Small amounts of manganese in leaded fuel decrease valve life by about 25%, but this can be overcome with phosphorus additions or by increasing manganese concentrations which then, however, reduce spark plug life. It is claimed, on the basis of limited mileage road tests, that manganese at concentrations of 0.125 g/gal. has no adverse effects on the performance of monolithic oxidant catalytic converters (27). However, extended model tests, using 0.25 g/gal. manganese, demonstrate back-pressure effects due to mechanical plugging of catalysts by the non-volatile manganese oxides (18). Ethyl is reported to be currently developing a hardware approach to obviate plugging problems in monolithic catalysts; additionally, EPA is studying this problem in beaded catalysts of the GM type (24).

The present production of manganese fuel additives is about 1 million lbs. a year, of which approximately 90% is used for stationary sources and 10% for mobile sources (25); its projected use as a primary anti-knock in gasoline in the next few years is about 15 million lbs. annually. In view of this anticipated increase, the problem of increased manganese emissions from mobile sources needs critical consideration. It has been estimated by industry that widespread use of manganese could produce increments in median ambient urban air levels from 0.05 to 0.2 $\mu g/m^3$ (27). However, EPA estimates, based on model considerations, indicate that levels as high as 1 to 5 $\mu g/m^3$ could be reached in traffic corridors (29). It should be recalled that TLV levels for occupational exposure to manganese are 5 mg/m^3. While exposure to high levels of manganese is recognized as an occupational cause of pneumonitis and a Parkinsonian syndrome (30), the margin of safety for large urban populations near traffic corridors following large scale use of manganese anti-knocks has not yet been defined. The possible catalytic oxidation of atmospheric SO_2 by high levels of manganese, which has been claimed to be negligible in preliminary model studies (31), also requires further consideration, as does the possible adverse effects of manganese on the performance of oxidant catalysts.

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IV. POLICY OPTIONS

There are various policy options with regard to reducing automobile lead emissions.

A. Reliance on Regulations on Lead-free Gasoline

Regulations requiring the availability of lead-free (less than 0.05 g/gal.) and phosphorus-free (less than 0.005 g/gal.) gasoline of at least 91-octane, minimally one grade to be available at all gasoline stations for 1975 and subsequent model year cars, were promulgated in the Federal Register on January 10, 1973. These regulations were predicated on the anticipated use of lead-intolerant oxidation catalysts to meet the requirements of the 1970 Clean Air Act Amendments for hydrocarbon and carbon monoxide emissions.

Reliance on regulations requiring the availability of lead-free gasoline alone will not necessarily achieve a major immediate reduction in lead emissions. Apart from in-use vehicles using leaded gasoline, it is likely that alternate power systems, such as rotary and stratified charge, using leaded fuel and capable of achieving 1975-76 standards without catalysts, will become generally available in the early future. The use of manganese anti-knocks in lead-free gasoline, needs careful examination with regard to non-regulated emissions, particularly of manganese (see Section III, F 2), and with regard to possible adverse effects on catalyst performance.

"Trade-offs" for the introduction of lead-free gasoline and catalytic converters include high investment costs. Additionally, there will be a high fuel economy penalty when the 1976 statutory standards for hydrocarbons, CO and NO_x are implemented by the use of catalysts requiring lead-free fuel; however, alternate power systems offer the opportunity of achieving these statutory standards with leaded fuel without a significant fuel penalty. It must be recognized that if the 1975 interim emission standards are continued in future use, a minor fuel economy benefit would be realized compared to 1974 economy levels. An additional fuel penalty of approximately 1% in gasoline production would result from desulfurization of gasoline, to reduce sulphate emissions from catalyst-equipped vehicles; such emissions may pose serious public health hazards and thus challenge the basic premise of the Clean Air Act. Additional, but more uncertain trade-offs include the possibility of other non-regulated emissions from oxidant catalytic converters, particularly of platinum and palladium, and the possibility of poor performance of converters under conditions of general use. However, given satisfactory performance of converters, the potential negative impact of some of these trade-offs may be minimized by policies recongizing the possible interim nature of their usage, pending the resolution of outstanding technological and public health questions on converters and on alternate power systems.

B. Promulgation of Regulations on Reduction of Lead in Gasoline

Regulations providing for the reduction of lead in all grades of leaded gasoline were proposed in the Federal Register on February 23, 1972, providing for a maximum of 2 g/gal., effective January 1, 1974, and also for a phased reduction to 1.25 g/gal. by January 1, 1977. These regulations were re-proposed in the Federal Register on January 10, 1973, deferring the reduction schedule by one year, and promulgated on December 6, 1973, requiring a stepwise reduction of maximum lead levels in the total gasoline pool to 0.5 g/gal. by January 1, 1979. New York City has already imposed the most stringent restrictions in the U.S. leading to a complete phase-out of lead in gasoline by January 1, 1974.

These regulations, together with the availability of lead-free gasoline for 1975 model year cars, are likely to achieve EPA stated objectives of 60% to 65% reduction in lead emissions by 1979. These projections are based on current national average lead concentrations of 2.2 g/gal., ranging from 2 to 3.6 g/gal. However, these estimates ignore emissions from re-entrained lead currently stored in the exhaust systems and engines of in-use vehicles; this may be significant, particularly in the first year or two following implementation of the "phase-out" regulations.

The promulgated reduction schedule of December 6,1973, would minimize adverse impacts on fuel availability and allow orderly reshifting of refinery operations in order to meet increased aromatic requirements. Estimates on the adverse impacts of fuel availability, however, vary widely from EPA values of 0.4% crude (1% gasoline) to estimates of 15% crude by PPG; refinery industry estimates are in the region of 1% to 1.5% crude. Total energy deficits, from the January 10, 1973 lead-free regulations and from the December 6, 1973 regulations on stepwise reduction in lead, would be correspondingly greater (See III F1), although estimates for this vary widely. Octane ratings could be maintained by increasing fuel aromatics in parallel with the lead reduction schedule. Resulting increases in polynuclear aromatic hydrocarbon emissions could be effectively reduced in parallel with the required emission reductions

C. Use of Lead Traps

Several trap systems have been developed and tested, particularly by Du Pont, which are efficient and practical and which can be retro-fitted or adapted to new cars. These do not require owner maintenance and extend typical current muffler life from approximately 38,000 to 100,000 miles. Traps are a highly cost-effective method of reducing lead emissions without any attendant fuel penalties and without any need to alter current refining capacities. They can be used to retro-fit in-use vehicles, using gasoline leaded at current average concentrations of 2.2 g/gal. or at projected 1979 levels of 0.5 g/gal. in the total gasoline pool, in accordance with the EPA regulations promulgated on December 6, 1973.

While it is recognized that the EPA Administrator does not appear to have the authority to prescribe lead emission standards for other than new vehicles, an alternate lead abatement strategy could be developed requiring trap systems in all replacement mufflers; at relatively low costs, most in-use vehicles could be fitted with traps in the next few years. The cost-effectiveness of traps for new cars with alternate power systems appears greater than for in-use vehicles. Performance standards, in terms of lead or total particulate emissions levels, could be promulgated to achieve desired reductions in lead emissions.

Emission standards could be developed for lead or more simply for total air-diluted particulates, e.g., 0.01 to 0.005 g/mile. A general particulate standard would not only act as a performance standard for traps, but would also regulate various "non-regulated" emissions, including lead, polynuclear aromatics, aldehydes and pheonols. Emission standards could be designed to yield ambient air lead levels in the region of 2 $\mu g/m^3$ or less; currently proposed California ambient standards are 1.5 $\mu g/m^3$. Total particulate standards could also be applied for in-use vehicles in certain regions, e.g., in Air Quality Control Regions, where ambient air quality standards could not otherwise be achieved without additional transportation controls. These could be enforced when worn mufflers are replaced or when in-use cars are sold.

Apart from the cost effectiveness of traps for the consumer, their use would preclude or limit refinery construction costs and costs of alterations in refinery capacity necessary to produce non-leaded high octane-fuels. The long-term need for high octane fuel will, in all likelihood, diminish progressively with the further development of alternate propulsion technologies less dependent on compression ratios and fuel-burning qualities than are conventional internal combustion engines.

The use of traps with required performance standards is likely to achieve a greater reduction in lead emissions than that achievable by the "phase-out" regulations, particularly if lead-tolerant alternate power systems are introduced into the domestic market in addition to catalyst-equipped vehicles. It must also be emphasized that a much more dramatic reduction in lead emissions would be effected by retrofitting traps on in-use vehicles, additionally. It is difficult at this stage to make comparisons regarding the relative effectiveness of traps versus "phase-out" regulations for the early 1980's, due to uncertainties as to the anticipated ratio of the number catalyst-equipped vehicle to lead-tolerant alternate power system vehicles. Assuming a high percentage of alternate power system vehicles using leaded fuel at 0.5 g/gal., then lead emissions will still be relatively high in the early 1980's and will increase with increased marketing of such vehicles.

D. Use of Lead Traps in Conjunction with the "Phase-Out" Regulations

An option which merits consideration, particularly from a long-term standpoint, could be the use of traps in addition to the "phase-out" regulations. This could be the optimum solution for reducing lead emissions, besides other particulate emissions, and for maintaining effective reductions in mobile source lead emissions over the next decade or so.

Mr. ROGERS. Thank you so much for your presence.

Our last witness here is Mr. Clarence Ditlow, the Public Interest Research Group, Washington, D.C. We will need to finish soon, because we will be called to a quorum before long.

Mr. Ditlow, we welcome you to the committee. If you can point up the things you think this committee ought to hear quickly, your full statement will be made a part of the record.

STATEMENT OF CLARENCE M. DITLOW, PUBLIC INTEREST RESEARCH GROUP

Mr. DITLOW. Yes. I will abbreviate for purposes of expediency.

First, we think it is inappropriate to consider adding to the present energy emergency bill any proposals to weaken automobile emission standards in 1975 or later model years. No change in the auto emission standards will ease the crisis this winter. Regarding next winter, the evidence indicates that the use of catalyst technology to meet 1975 standards will produce a significant fuel savings. Thus, we come to the question of what, if anything, should be done about the 1976 model year. This we submit is a question that cannot be adequately addressed in the few weeks that Congress is devoting to the many complex issues in the energy emergency legislation.

With respect to the substance of the proposals before the committee, we oppose any change from the present schedule for the emissions standards of 1975 through 1977. Since these standards are essential to the achievement of healthy air quality, they should not be delayed unless the need to delay exists, a need which outweighs public health. In our view, no need has been shown.

We are glad to see the growing recognition that cars do, indeed, use too much energy; but autos use too much fuel primarily because of their increased usage. Between 1950 and 1970 energy consumption increased 171 percent. Only 11 percent of this consumption was due to decreases in fuel economy. Thus, reducing auto use, especially in urban areas, offers major energy conservation potentials. For example, it has been calculated that more than 13 billion gallons of gasoline could have been saved if 40 percent of urban auto travel in 1970 had been shifted to public transportation, with an additional 10 percent of the short trips made on foot or by bicycle. If any Federal program needs to be questioned given the energy crisis, they are those such as the Federal Aid to Highway program, which assume and cause ever increasing auto use.

Large energy savings are possible through improved fuel economy also. Major improvements in fuel economy are possible by reducing vehicle weight. EPA calculates that reducing auto weight to a 2,500 pound maximum could save 2.1 million barrels of crude oil per day in 1985. Auto equipment changes offer additional savings. The issue is what equipment should be the first target for change. We submit that it is an indefensible policy to ban new emission control equipment which protects health before prohibiting existing luxury equipment, which wastes even more gas.

Accordingly, we recommend if this committee decides to act now to improve auto fuel economy, it do so by prohibiting installation of luxury equipment on new cars and not by delaying installation of emission devices. Specifically, we recommend the prohibiting of the use of air-conditioners in new cars. EPA estimates that air-conditioning a car can cause as great as a 20-percent fuel penalty in summer stop and go driving conditions and cites average fuel penalty for the use of air-conditioners in cars as 9 percent. Chrysler Corp. has observed a 15-percent fuel penalty. For purposes of this discussion I will assume a mid-range penalty of 12 percent. In 1972, 70 percent of all cars were equipped with air conditioning with a sales weighted fuel penalty for that year of 8.4 percent. Assuming the same percentage of air conditioners would be installed on approaching model years, which is indeed a conservative estimate because they have been increasing significantly each year, a decision not to install air-conditioners would improve fuel economy by 13.8 percent for each car and 9.2 percent for the fleet as a whole.

If we assume that air-conditioners are in use from one-third to one-half the time, then the average fuel economy gain will be from 3.1 to 5.4 percent. This means that beginning in 1975 the Nation could save anywhere from 380 to 656 million gallons of gasoline in the first year, 1.0 to 1.8 million gallons per day; during 1976 it increases up to 1.2 billion gallons of gasoline, which is the equivalent of 3.4 million gallons per day; and for 1977 the savings would reach 1 to 1.8 billion gallons of gasoline, which is 2.8 to 4.9 million gallons per day.

But this is just one of several equipment changes that can save fuel without endangering health. Items such as the power sunroof, power windows, power seats, or power brakes might be additional candidates. The use of radial tires rather than the normal bias-ply tires can improve fuel economy an additional 3 percent.

Any fuel economy gain accomplished by delaying 1976 emission standards is equalled or exceeded by the fuel economy gain from not installing air-conditioners. Using GM data a car meeting 1976 standards would get about 0.4 miles per gallon less than a car at the interim 1975 levels, or about 3 percent poorer fuel economy. Thus, keeping the standards at the 1975 levels rather than 1976 would be no more effective and quite possibly less effective in conserving energy than not installing air-conditioners. More importantly, delaying the emission control equipment would have an adverse public health impact.

Thank you.

[Testimony resumes on p. 546.]

[Mr. Ditlow's prepared statement and attachments follows:]

STATEMENT OF CLARENCE M. DITLOW, PUBLIC INTEREST RESEARCH GROUP

Thank you for your invitation to testify before this committee. First let me state that we think that it is inappropriate to consider adding to the present energy emergency bill any proposals to weaken automobile emissions standards in 1975 and later model years. No change in any auto emission standard will ease the energy crisis in the least this winter. Regarding next winter, the evidence indicates that the use of catalyst technology to meet presently scheduled 1975 standards will produce a significant fuel saving. Thus, we come to the question of what, if anything, should be done about the standards scheduled for model year 1976. This, we submit, is a question that cannot be adequately addressed in the few weeks that Congress is devoting to the many complex issues in the emergency energy legislation. Any decisions made on the auto standards will fix the pollution levels for cars that will be on the roads for 10 years. A decision with these consequences should be subject to more than a few days' notice and one afternoon of hearings. Since a change in the scheduled 1976 or 1977 standards would not even be applicable for 2 to 3 years there is no need to consider such changes in the present crisis-charged atmosphere.

With respect to the substance of the proposals before the committee, we oppose any change from the present schedule for emissions standards for 1975, 1976, and 1977. Since these standards are essential to achievement of healthful air quality in our cities in the near future, they should not be delayed unless a need to delay—a need which outweighs human health—is shown. In our view no one has yet shown any such need. The argument of the day is that such delays might be required to deal with the energy crisis. Let us examine that.

We are glad to see a growing recognition that cars do indeed use too much energy. However, making emission control devices the first area of concern indicates a topsy-turvey set of priorities. Autos use too much fuel both because of excessive use and because of the way they are built and equipped. Between 1950 and 1970 annual auto energy consumption increased 171%. Eighty-nine percent of this increase was caused just by growth in auto use; only 11% was due to decreases in fuel economy.[1] Thus, reducing auto use, especially in urban areas, offers major energy conservation potential. For example, it has been calculated that more than 13 billion gallons of gasoline could have been saved if 40% of urban auto travel in 1970 had been shifted to public transportation, with an additional 10% of the mileage (the very short trips) made on foot or by bicycle.[2] EPA's transportation control plans will help to achieve energy savings through reduced auto use. Congress can make further gains by pressing for enactment of mass transit operating subsidies, overriding a presidential veto if necessary. If any Federal programs need to be questioned, given the energy "crisis," they are those such as the Federal-aid highway program, which assume and cause ever increasing auto use. Suspend the highway trust fund, not the Clean Air Act!

Large energy savings are possible through improved fuel economy also. Major improvements in fuel economy are possible by reducing vehicle weight. EPA calculates that reducing auto weights to a 2,500-pound maximum could save 2.1 million barrels of crude oil per day in 1985. Auto equipment changes offer additional savings. The issue is what equipment should be the first target for change? Mr. Dibona asks that we drop tighter emission controls first. We submit that it is indefensible policy to ban new emission control equipment, which protects health, before prohibiting existing luxury equipment which wastes even more gas.

Accordingly, we recommend that if this committee decides to act now to improve auto fuel economy, it do so by prohibiting installation of luxury equipment on new cars and not by delaying installation of emission devices. Specifically, we recommend prohibiting the use of air conditioners in new cars. EPA estimates that air conditioning a car can cause as great as a 20% fuel penalty in summer stop and go driving conditions and cites average fuel penalty for the use of air conditioners in cars as 9%.[3] Chrysler Corporation has reportedly observed a 15% fuel penalty on cars using air conditioning in urban driving. For purposes of this discussion, we'll assume a mid-range penalty of 12%. Since 70% of all new cars in 1972 were equipped with factory-installed air conditioning, the sales-weighted average fuel penalty for the 1972 model year production was 8.4%. Assuming the same percentage of air conditioners would be installed on approaching model years, a decision not to install them would improve fuel economy 13.8% for each car which would have been equipped and 9.2% for the fleet as a whole.

Since we assume that not all owners of air conditioned cars run their air conditioners all the time, the average fuel economy gain on an annual basis will be less than these figures. If we assume (conservatively, we feel) that air conditioners are in use from one-third to one-half of the year, then the average fuel economy gain will be from 3.1 to 5.4%. If an auto air conditioner moratorium were begun for the 1975 model year the Nation could save from 380 to 656 million gallons of gas in the first year (1.0–1.8 million gallons/day); during the 1976 model year between 725 million and 1.2 billion gallons could be saved (2.0–3.4 million gallons/day): for 1977 the savings would reach 1 to 1.8 billion gallons (2.8–4.9 million gallons/day).

This is just one of several equipment changes that can save fuel without endangering health. Items such as the power sunroof, power windows, power seats, or power brakes might be additional candidates. The use of radial tires rather than normal bias-ply tires can improve fuel economy an additional 3%.

Any fuel economy gain accomplished by delaying 1976 emission standards is equalled or exceeded by the fuel economy gain from not installing air conditioners. Using General Motors data a car meeting 1976 standards would get about 0.4 miles per gallon better than a car at the interim 1975 levels, or about 3% better fuel economy. Thus, keeping the standards at 1975 levels rather than 1976 would be no more effective and quite possibly less effective in conserving energy than not installing air conditioners. More importantly, delaying the emission control equipment would have an adverse public health impact.

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[1] E. Hirst and R. Herendeen, "Total Energy Demand for Automobiles." Paper presented at Society of Automotive Engineers, Annual Meeting, Detroit, January 1973, at p. 5.

[2] *Idem.*, p. 6.

[3] U.S. EPA, *A Report on Automobile Fuel Economy*, October 1973, at p. 16.

If the choice must be made on limiting auto equipment use to save energy, vote to give the public clean air over cold air.

AIR CONDITIONER INSTALLATIONS

	1972 model year			1971 model year		
	Unit total	Percent of output	Percent of 1972 air-conditioner installations	Unit total	Percent of output	Percent of 1971 air conditioner installations
American Motors	125,181	48.31	2.09	82,303	33.63	1.75
Ambassador	40,912	92.22	.68	38,766	93.00	.82
Hornet	26,509	37.31	.44	10,747	14.40	.23
Gremlin	16,489	26.72	.28	6,042	11.30	.13
Matador-Rebel	27,132	49.49	.45	15,771	34.40	.34
Javelin-AMX	14,139	52.03	.24	10,977	37.70	.23
Chrysler Corp	856,759	63.83	14.31	761,207	60.59	16.21
Chrysler-Plymouth Division	566,769	65.57	9.47	501,166	39.89	10.67
Valiant	83,084	32.40	1.39	64,681	26.60	1.38
Barracuda	6,365	34.50	.10	4,646	29.60	.10
Satellite-Belvedere	52,583	64.70	.88	76,687	56.40	1.63
Fury	228,308	85.00	3.82	207,330	82.90	4.41
Total Plymouth	370,340	57.83	6.19	353,344	28.13	7.52
Chrysler	180,635	93.10	3.02	136,982	89.70	2.92
Imperial	15,794	100.00	.26	10,840	100.00	.23
Dodge Division	289,990	60.83	4.84	260,041	20.70	5.54
Dart	52,907	41.30	.88	9,626	34.20	1.48
Coronet-Charger	101,754	68.70	1.70	91,919	62.60	1.96
Challenger	12,505	46.90	.21	12,566	48.20	.27
Polara	122,824	88.60	2.05	85,930	87.90	1.83
Ford Motor Co	1,555,539	66.67	25.97	1,335,575	56.79	28.43
Ford Division	1,147,596	62.98	19.16	1,026,462	53.36	21.85
Torino-Fairlane	245,311	68.10	4.10	153,813	50.80	3.27
Ford	680,039	85.60	11.35	700,628	80.60	14.91
Mustang	60,670	48.50	1.01	54,893	40.54	1.17
Thunderbird	57,178	98.90	.95	33,117	98.05	.71
Maverick	40,399	29.50	.68	52,025	20.40	1.11
Pinto	63,999	18.40	1.07	31,986	9.78	.68
Lincoln-Mercury Division	407,943	79.53	6.81	309,113	72.23	6.58
Lincoln	45,969	100.00	.77	35,551	100.00	.76
Mark IV	48,591	100.00	.81	27,091	100.00	.58
Montego	103,075	76.30	1.72	33,286	58.30	.71
Mercury	137,665	93.50	2.30	146,117	90.00	3.11
Cougar	43,606	81.20	.73	47,148	75.00	1.00
Comet	29,037	35.30	.48	19,920	23.99	.42
General Motors	3,450,494	74.62	57.61	2,517,451	69.31	53.59
Buick Division	594,597	87.45	9.93	462,115	83.80	9.84
Buick	391,827	93.10	6.54	301,082	90.33	6.41
Riviera	33,397	99.02	.56	33,233	98.29	.71
Century	169,373	75.16	2.83	127,800	69.43	2.72
Cadillac Division	264,290	99.64	4.41	185,460	98.37	3.95
Cadillac	224,302	99.58	3.75	158,202	98.16	3.37
Eldorado	39,988	99.79	.67	27,258	99.60	.58
Chevrolet Division	1,371,192	60.36	22.89	983,805	55.67	20.94
Chevelle	224,711	62.80	3.75	203,809	55.27	4.33
Nova	96,526	26.23	1.61	38,449	19.73	.82
Chevrolet	766,390	84.54	12.80	549,107	81.16	11.69
Corvette	17,266	63.79	.28	11,481	52.66	.24
Camaro	31,737	46.23	.53	42,537	37.11	.91
Monte Carlo	149,321	91.56	2.49	98,412	87.40	2.10
Vega	85,241	21.83	1.42	40,010	14.41	.85
Oldsmobile Division	656,241	86.55	10.96	461,900	82.42	9.83
Cutlass	260,424	77.84	4.35	192,772	72.99	4.10
Oldsmobile	347,353	92.70	5.80	240,297	89.98	5.12
Toronado	48,464	99.11	.80	28,831	98.52	.61
Pontiac Division	564,174	79.80	9.42	424,171	72.28	9.03
Pontiac	309,618	90.45	5.17	227,142	86.93	4.84
LeMans-Tempest	120,109	70.65	2.01	100,562	60.71	2.14
Firebird	19,961	66.64	.33	30,494	57.39	.65
Grand Prix	88,941	96.71	1.48	55,157	94.56	1.17
Venture II	25,545	35.09	.43	10,817	22.31	.23
Checker Motors	1,001	19.13	.02	805	16.80	.02
Total	5,988,974	70.00	100.00	4,697,341	62.40	100.00

Note: Ford Division volume figures were derived by applying percentages based on North American-built cars sold in the United States to U.S. Ford Division production. Lincoln-Mercury and Chrysler Corp. volume figures were derived by applying the installation rate of the respective companies' North American production to their U.S. output.

U.S. ENVIRONMENTAL PROTECTION AGENCY,
NATIONAL ENVIRONMENTAL RESEARCH CENTER,
Research Triangle Park, N.C., November 15, 1973.

Subject: Evaluation of Health Basis for Japanese NO_2 Standard.
From: OD/HSL.
To: Director, NERC/RTP.

The Japanese NO_2 standard was recently established at 0.02 ppm (38 $\mu g/m^3$) 24-hour maximum. This standard is considerably lower than the U.S. primary ambient air quality standard of 100 $\mu g/m^3$ (0.05 ppm) annual average, which would project to 250 $\mu g/m^3$ (0.13 ppm) 24-hour maximum. Thus the Japanese NO_2 standard is approximately 6 to 7 times more stringent than the equivalent U.S. standard.

The Japanese NO_2 standard appears to be based on two epidemiological studies: (1) a study of chronic bronchitis in male local government workers in the Tokyo metropolitan area from 1968–1970, and (2) a study of chronic bronchitis among housewives age 30 or more living in six localities throughout Japan, conducted during the Winter of 1970–1971. The full reports of these two studies are not as yet available in the U.S., but the results are summarized in Reference 1. My comments are necessarily limited to the data available in this summary report.

In the Tokyo study, the prevalence rate of chronic bronchitis was found to be 5 percent in those areas where the annual NO_2 concentration was 0.042 ppm (79 $\mu g/m^3$) while sulfur dioxide was below 0.05 ppm (130 $\mu g/m^3$). In non-polluted Japanese communities, chronic bronchitis prevalence rates did not exceed 3 percent. These prevalence rates are found only among nonsmokers in the U.S. Bronchitis prevalence rates among smokers vary from 10 percent in light to 20–25 percent in heavy smokers. Therefore, I assume that only nonsmokers were included in the Tokyo survey. The summary report provides no information on important population determinants of chronic bronchitis, such as age, smoking, occupation, social class and residential history. Even if these determinants were accounted for, it would be difficult to attribute the 2 percent excess bronchitis rate observed in Tokyo to current NO_2 concentrations. We know from other epidemiologic studies of air pollution health effects in Tokyo that concentrations of particulate matter and sulfur dioxide during the 1960s were far in excess of the U.S. national primary standard. Cumulative exposure to these high levels would be a more likely cause, or contributor to, the observed excess bronchitis rates. Furthermore, even if other pollutant levels were not greatly elevated, the excess chronic bronchitis rates should be associated with annual averaging times rather than a 24-hour maximum, since most epidemiologic evidence implicates cumulatie, long-term exposures as the causal agent in chronic bronchitis.

In the 6 region housewife survey, pollutant concentrations were determined during a three month period, in the Winter of 1970–1971; measurements were obtained for 8–72 hours during each month, for a maximum of 9 days during the 90 day study period. The following respiratory symptom rates and pollutant concentrations were reported in the survey report.

	Location					
	Sakara City, Chiba	Ichihera	Tonda-bayashi, Oseka	Fuse, Osaka	Fukuoke-West, Kyushio	Ohmuta, Kyushu
Cough (percent)	3.5	4.8	3.0	7.9	5.8	9.4
Phlegm (percent)	4.1	5.3	4.3	11.0	12.3	11.0
NO_2 (parts per million)	.015	.013	.017	.077	.042	.020
SO_2 (parts per million)	.024	.027	.013	.050	.010	.042
TSP $\mu g/m^3$	196	352	111	350	183	498

Chronic bronchitis prevalence rates exceeded 5 percent only in those areas in which NO_2 concentrations were .042 ppm or above. However, total suspended particulate (TSP) concentrations vere very high, ranging from twice to six times the U.S. primary standard.

The correlation coefficient between prevalence of persistent cough and phlegm and each pollutant are as follows:

Pollutant	Correlation with symptom prevalence
NO_2	0.71
SO_2	0.68
TSP	0.65
NO	0.88
$NO+NO_2$	0.85
CO	0.82

These correlation coefficients do not greatly differ from one another and indicate that the pollutant-disease association cannot be ascribed to NO_2 alone. Given the high concentrations of TSP, and the relatively low levels of other pollutants, one would tend to incriminate particulate matter (or some correlate such as suspended sulfates and/or nitrates) as the offending agent.

We are given no information on past exposures in these communities. Furthermore, a sampling frequency of 1 in 10 days for a three month period is unlikely to provide a reasonable estimate of average NO_2 concentrations. Likewise, the chronic bronchitis experience should be related to long-term cumulative exposures rather than to a 24-hour maximum level. Information on other determinants of bronchitis frequency is lacking and would be particularly important in a survey of six disparate communities. The original and complete reports of these surveys may contain the additional information. Until more data are available, the association of excess bronchitis rates with maximum 24-hour NO_2 concentrations of 0.042 ppm or above should be held as suppositional, at best. As in the Tokyo study, past high exposures to SO_2 and particulates are more reasonable correlates of excess bronchitis in the more polluted communities.

Available Japanese data, therefore, do not warrant a change in the U.S. national primary standard. Even if the effect of other pollutants and of other disease determinants were discounted, the Japanese data would suggest under worst case assumptions an association of excess bronchitis with annual mean rather than maximum one-hour NO_2 concentrations of 0.042 ppm. The paucity of information on study methods and monitoring techniques provides us only with qualitative data, or weak quantitative values; such data are clearly insufficient as a basis for a precise standard.

The value of the Japanese studies lies in their qualitative confirmation of experimental results in animals, namely, that NO_2 exposure can produce lung tissue changes similar to that found in cases of human chronic respiratory disease. Heretofore, no human evidence on chronic bronchitis supported the experimental findings. The Japanese results may also be interpreted, from the viewpoint of protecting public health, as a warning against any relaxation of NO_2 emission standards. If the Japanese data can be scientifically accepted and if additional studies support the chronic bronchitis-NO_2 association, the 0.4 gram/mile NO_2 emission standard may be fully supportable. Given our uncertainty, I believe that further reductions in NO_2 emission rates (below current 3.0 gram/mile levels) are both sensible and highly desirable from a public health viewpoint. This contention is reinforced by our concern for the potential adverse effects of the atmospheric degradation products of NO_2, namely nitric acid aerosols and nitrate particles. Recent CHESS surveys of asthmatics in New York have shown a significant correlation between daily nitrate, as well as sulfate, concentrations and asthma attack rates. Because of the small size of nitrate particles, nitrate pollution is likely to be an area-wide problem requiring more stringent roll-back of NO_2 emissions in order to achieve reductions in area-wide nitrate levels.

CHESS studies are providing data on chronic bronchitis rates in relationship to suspended nitrates, sulfates, NO_2 and oxidants. We cannot easily isolate the effects of any one of these pollutants on chronic bronchitis prevalence rates. However, in the California CHESS areas, we may be able to discriminate between the effects of daily NO_2, nitrates, sulfates and oxidants on aggravation of illness in cardiopulmonary subjects and asthmatics. These studies are in progress, and preliminary results should be available within 8 months.

CARL M. SHY, M.D.,
Director, Human Studies Laboratory.

Reference: 1. Report of the Expert Committee on Air Quality Criteria for Oxides of Nitrogen and Photochemical Oxidants. Central Council for control of Environmental Pollution, Sub-Council for Air Pollution Control, June 20, 1972.

STATEMENT OF CLARENCE M. DITLOW, PUBLIC INTEREST RESEARCH GROUP, BEFORE THE SENATE COMMITTEE ON PUBLIC WORKS—NOVEMBER 6, 1973

Mr. Chairman, distinguished members of the Senate Committee on Public Works, thank you for the invitation to express some comments on the Clean Air Act with particular emphasis on motor vehicle emissions. My name is Clarence M. Ditlow, III. I am a member of the Public Interest Research Group, a group of lawyers, engineers and scientists established by Mr. Ralph Nader.

When the Clean Air Amendments of 1970 were enacted, there was broad public expectation that the auto industry would begin to work in good faith to protect the citizen from the dangers associated with exposure of air pollution from motor vehicles by reducing the emissions thereof to the low levels required for 1975 and 1976. Instead, misallocated research efforts and low priority within the domestic industry have led us to the critical point under consideration in these hearings—the vitality of the Clean Air Act in view of the seeming inability of the domestic manufacturers to develop a low-polluting, efficient propulsion system for the automobile.

Under the suspension provisions of the 1970 Amendments, the major domestic manufacturers have obtained deferral of the statutory 1975–1976 standards until 1976–1977. Close examination of the domestic industry's claims of technological inability to meet the 1975 carbon monoxide (CO) and hydrocarbons (HC) standards strongly suggests the manufacturers used environmental blackmail tactics to obtain a suspension from the Environmental Protection Agency (EPA). When former Administrator Ruckelshaus granted the one year suspension of the 1975 standard, he stated:

"The most compelling factor in my decision to require phase-in of catalysts in 1975 has been the possibility raised by the evidence that if the automobile industry attempts to install catalytic converters on its entire product line, without a scale-up period of limited mass production in which to gain experience, difficulties such as a shortage of vital parts or materials, inaccurate machining tolerances, or defects in assembly techniques will arise, and may well be severe enough to cause significant economic disruption."

In commenting on the technical presentations of the auto manufacturers which had convinced him of this point, Mr. Ruckelshaus stated, "The company which has laid the most stress on this point [production problems] is General Motors." Some of the General Motors' testimony that Mr. Ruckelshaus relied on included the following dire statement:

"[I]f GM is forced to introduce catalytic converter systems across the board on 1975 models, the prospect of an unreasonable risk of business catastrophe and massive difficulties with these vehicles in the hands of the public must be faced.

"It is conceivable that complete stoppage of the entire production could occur, with the obvious tremendous loss to the company, shareholders, employees, suppliers, and communities. Short of that ultimate risk, there is a distinct possibility of varying degrees of interruption, with sizable dislocation." [1]

Before two months had passed with the non-catalyst requiring interim standards safely in hand, what did the prime opponent (General Motors) of the mandatory catalysts do? Merely announced the installation of catalysts across the board in 1975 according to a June 17, 1973, statement by General Motors President Edward N. Cole.[2] Where did the production problems go—the risk of business catastrophe and the entire stoppage of production? Perhaps they were never there in the first instance but were merely conjured up for the purpose of obtaining a suspension concession from EPA. In any event the prophecies of doom have been replaced by claims that would have been regarded as preposterous exaggerations at the least if they were made by the catalyst manufacturers at the EPA hearings—claims of fuel economy gains up to 20% and catalysts that are durable not for 25,000 or 50,000 miles but for the life of the car.

Having obtained the maximum possible suspension under the Clean Air Act, the auto manufacturers now want the Congress to further delay and weaken the statutory hydrocarbons (HC) and carbon monoxide (CO) emission standards. Aside from the misrepresentations of the auto industry as to the effectiveness of emission control technology, this public health damaging request must be viewed in the historical context of the industry's refusal to develop and apply

[1] EPA Suspension Hearing Transcript at 29–30.

[2] The Statement was given in an interview with Robert W. Irvin of the *Detroit News* and was reported in the *Detroit News* on the same day. A copy of this article along with other articles describing GM's catalyst program is submitted for the record.

effective pollution control technology including alternatives to the traditional internal combustion engine.

Pollution control and the domestic auto industry

Since the Forties, the auto manufacturers knew that their cars were related to the periodic smog which would occur in Los Angeles. In the early Fifties, independent scientists proved that auto exhausts contributed to photochemical smog. During the Fifties and early Sixties, California pollution control authorities demanded without success that auto manufacturers control their vehicle emissions.

In 1969 the real reason for the auto industry's uniform unwillingness to clean up its engines came to light when the Justice Department filed an anti-trust suit against the domestic manufacturers and their trade association, the Automobile Manufacturers Association, for conspiring to restrain the development and marketing of auto exhaust control systems since early 1953. The evidence brought together prior to this suit by a Los Angeles grand jury outlined the cross-licensing agreement and other close associations between these so-called auto competitors that forged this illegal, united front of inaction. The Grand Jury wanted to indict the companies but the Justice Department filed a civil suit instead in January 1969.[3] In September 1969, the domestic auto companies entered into a consent agreement with the government agreeing never to engage in such a conspiracy again.[4]

Even where the auto industry puts emission controls on vehicles, it has attempted to impair their functioning. Thus EPA discovered the major domestic manufacturers were installing emission control defeat devices on their 1973 vehicles. These "defeat devices," under certain driving conditions or ambient temperatures, automatically disable at least part of the mandatory emission control system and cause higher emissions. Effective February 1, 1973, and March 15, 1973, EPA ordered the removal or replacement of the defeat devices from more than 2,000,000 vehicles to be manufactured by General Motors, Ford, Chrysler and American Motors.[5] Vehicles with defeat devices manufactured prior to those dates were not required to be recalled for elimination or replacement of the defeat devices.

Ford, which is misleading the public in a grass roots campaign for weakening the Clean Air Act,[6] has the worst record for illegal activities under the Clean Air Act. In addition to installing illegal defeat devices, Ford shipped 200,000 1972 models to its dealers before EPA approved their emission control systems in clear violation of the Clean Air Act and EPA's implementing regulations. This knowing violation resulted in a \$10,000 fine—a mere nickel a car. Perhaps encouraged by the government's failure to meaningfully penalize Ford in 1971, Ford massively cheated on their emission control certification tests in 1972. When this criminal violation of the Clean Air Act was discovered, Ford successfully bought off criminal prosecution and potential jail sentences for its responsible officials by paying a seven million dollar fine with Justice Department approval.[7]

That is a partial background of the industry which seeks further delays in meeting the 1975 HC and CO emission standards, the industry which asks the public to continue breathing the excessive HC and CO emissions from motor vehicles with resultant damage to the public health. How much credibility can be given to the auto industry which has not stopped at legal means to advance its own interests? Very little, I suggest.

On the other hand, EPA has testified that the technology is clearly available to meet the original 1975 HC and CO emission standards. The National Academy of Sciences (NAS) in its February 1973 report on motor vehicle emissions supports EPA's position. The smaller manufacturers from the less monolithic foreign auto industry have proven it with alternatives to the traditional internal combustion engine.

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[3] On May 18, 1971, Congressman Burton inserted in the Congressional Record the confidential memorandum of the U.S. Department of Justice recommending to the Attorney General that criminal charges be brought against American automobile manufacturers for conspiring to restrain the development of a pollution-free motor vehicle. A copy of this document is submitted for the hearing record.

[4] A copy of the consent decree is submitted for the record along with the Justice Department press release on the decree and Mr. Ralph Nader's letter of September 15, 1969, to Assistant Attorney General Richard McLaren criticizing the consent settlement.

[5] Copies of EPA orders are submitted for the record.

[6] Copies of a Ford speech in Portland, Oregon, and an exemplary analysis thereof are submitted for the record.

[7] Copies of relevant Justice Department documents are submitted for the record.

Sulfuric acid emissions

Confronted with this documentation of technological feasibility, many opponents of the statutory motor vehicle emission standards are creating problems rather than resolving them to forestall the application of the emission standards. An earlier example was the domestic manufacturers' allegation that the Honda CVCC engine would not work in large U.S. cars. Faced with this U.S. accusation instead of experimentation, Honda was forced to convert a 350 cubic inch Impala to CVCC technology and meet the interim 1976 standards. The latest example is the sulfuric acid emission controversy which could and should be resolved by removing sulfur from gasoline.

Sulfuric acid or sulfate emissions from catalyst equipped motor vehicles are due to the oxidation of contaminant sulfur (S) in gasoline. Oxidation of S to sulfur dioxide (SO_2) and sulfur trioxide (SO_3) in internal combustion engines has been known and studied since at least as early as 1950.[8] If oxidation of S proceeds only to SO_2, then no sulfuric acid or sulfates are formed; merely SO_2 and possibly sulfurous acid (H_2SO_3). If S oxidation goes to SO_3, then sulfuric acid is produced by the reaction $SO_3+H_2O—H_2SO_4$. Sulfates are merely the salts of sulfuric acid. Even if only SO_2 is emitted from a motor vehicle, sulfuric acid is eventually produced in the atmosphere for some of the SO_2 is oxidized to SO_3 through subsequent chemical reactions.

Although suspended sulfates which are formed from sulfuric acid are thought to be the most harmful of the sulfur oxides (SO_x) pollutants, there is no ambient air quality standard for suspended sulfates nor will there be one for the next two to three years.[9] The existing ambient standard applies only to SO_2. EPA is reluctant to take a firm position on sulfates from auto emissions without an ambient standard for suspended sulfates. If nothing else, this controversy points out the immediate need for a suspended sulfate standard.

The data on sulfuric acid or sulfate emissions from motor vehicles are scattered and are only now being extensively gathered and evaluated. Most data are based on gasoline with 0.04% added by weight. Actual gasoline S content varies with unleaded gasoline having S levels two to three times lower than leaded gasoline. Since a catalyst equipped vehicle uses unleaded gasoline, it will emit less S products than a vehicle using leaded gasoline. Actual sulfate emissions depend upon the sulfate conversion efficiency (the percentage of S converted to sulfates or sulfuric acid) of the particular vehicle but low S gasoline clearly lowers sulfate emissions in comparison to high S gasoline. (This has been confirmed by Dr. William Balgord of the New York State Department of Environmental Conservation who reports virtually no sulfate emissions from his catalyst equipped vehicles which are run on leadfree Amoco premium gasoline.) Ironically, the highest sulfate emitting vehicle is the diesel since it has the highest sulfate conversion efficiency (up to 90%) and usually high S diesel fuel.[10]

Sulfate emissions from catalyst equipped vehicles range from 0.0001 grams/vehicle mile (g/vm) for General Motors vehicels on 0.02% S fuel to 0.09 g/vm (aged catalyst) to 0.18 g/vm (fresh catalyst) for Ford-Dow research on 0.067% S fuel. On 0.08% S fuel. GM reports 0.02 g/vm sulfate emissions. After adjusting for the S content of the gasoline, the primary difference between Ford and General Motors' data is apparently due to the higher platinum loading on the Ford catalyst—the higher the platinum loading, the higher the sulfate conversion efficiency and sulfate emissions. In addition, vehicles with aged catalysts (catalysts with above 500 to 1000 miles) have emission levels about one-half that of vehicles with fresh catalysts. Emission controls for HC and Co on late model non-catalyst vehicles can oxidize SO_2 to SO_3 with resultant sulfuric acid formation. EPA test results from Ann Arbor show 0.03 g/vm on such late model cars.

Considering all available evidence, catalyst equipped vehicles will emit no more than twice the sulfuric acid or sulfates than non-catalyst vehicles. Indeed, catalyst equipped vehicles may emit less or about the same amount of sulfates as non-catalyst vehicles when one considers the significantly lower levels of S in unleaded gasoline. And of course banning catalysts means many times higher emissions of HC and CO from new motor vehicles.

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[8] M. J. van der Zijden, van Hinte, J. E., van den Ende, J. C., "SO_2 and SO_3 In Exhaust Gases of Internal-Combustion Engines," 36 J. Inst. of Petroleum 561–74 (1950).

[9] Environmental Protection Agency, "Health Consequences of Sulfur Oxides: Summary and Conclusions Based Upon Chess Studies of 1970–1971," August 15, 1973.

[10] Department of Interior—Bureau of Mines, "Diesel Engines Underground, V. Effect of Sulfur Content of Fuel on Composition of Exhaust Gas," Report of Investigators 3713, June 1943.

If catalysts are put on some 1975 and virtually all 1976 cars and S is removed from gasoline, these cars will not have a sulfate problem and they will have significantly lower HC and CO emissions. If catalysts are not put on 1975 and later cars, they will have high HC and CO emissions regardless of what is done to the S in gasoline. If S is considered a problem for catalysts only, there is already sufficient low-S gasoline to begin a phase-in of catalysts in 1975 by requiring the gasoline be allocated to catalyst equipped vehicles.

If the catalyst alone presented a health hazard, then it should be barred from use until the hazard was removed. The sulfuric acid or sulfate emission problem is not presented by the catalyst alone. It is presented by the oxidation of contaminant S in gasoline by all late model vehicles. Removal of the catalyst will not significantly lower sulfate emission levels from new motor vehicles for remaining HC and CO controls will continue to oxidize contaminant S to SO_3 with resultant surfuric acid and sulfate formation. Only removal of S from gasoline will eliminate the problem of sulfuric acid or sulfate emissions from motor vehicles.

The breathing public needs the HC and CO standards as soon as possible. In 1975 29 Air Quality Control Regions with 43% of the nation's population will fail to meet the ambient air quality standards for CO or oxidants (HC). Transportation controls are necessary to reduce motor vehicle emissions in these areas. Further relaxation or extension of the HC and CO emission standards means more transportation controls will be imposed. Each additional year of relaxation means 10 years of relatively higher polluting vehicles on the road. The breathing public will have to bear the burden of motor vehicle pollution control rather than Detroit where the blame for the pollution and the technical expertise to control it lie. If transportation controls prove incapable of controlling emissions, then the public must pay for the difference in terms of illness and disease under the auto industry's legislative suggestions.

1976 oxides of nitrogen (NO_x) standard

The statutory 1976 NO_x standard, suspended until 1977, stands on different grounds from the statutory HC and CO emission standards—the need for this standard to enable the achievement of the NO_2 ambient air quality standard is in open dispute. According to former EPA Administrators, some 47 Air Quality Control Regions were originally said to be in violation of the standard but now there are said to be only two regions in violation. This position is based on the assertions that (1) actual ambient NO_2 levels are lower than those measured by the Federal Reference Method (FRM) and are below the NO_2 ambient air quality standard, and (2) the NO_2 ambient air quality standard (100 micrograms/cubic meter) is correct even though based on measurements taken by the allegedly erroneous FRM in the so-called Chattanooga study.[11]

Chattanooga study

The Chattanooga study is a health study conducted on school children in Chattanooga, Tennessee which effectively determined the NO_2 ambient air quality standard. Subsequent to the Chattanooga study, EPA determined that the FRM measuring technique used in that study and elsewhere in the country recorded levels of NO_2 about twice as high as they actually were. In current rulemaking, EPA proposes to replace the old FRM measuring technique with a new method that should accurately record NO_2 levels at about half the prior recorded levels. Yet EPA has not proposed to similarly reduce the NO_2 ambient standard by about half to reflect the more accurate NO_2 measurement. By changing the measuring technique without changing the standard, EPA is in effect proposing to about double the NO_2 ambient air quality standard without making this known to either the public or the Congress.

EPA apparently contends that the old FRM measuring technique was valid in Chattanooga and Chattanooga only. EPA has relied on Army and Public Health Service data taken at different times and places in Chattanooga by the Saltzman measuring technique to contend that the observed FRM NO_2 levels in the Chattanooga study were correct and should not be lower. EPA further

[11] Shy, C. M., J. P. Creason, M. E. Pearlman, K. E. McClain, F. B. Benson, M. M. Young; "The Chattanooga Schoolchildren Study: Effects of Community Exposure to Nitrogen Dioxide I–II".

relied on an unspecified meteorological model, but reported to be a simple mathematical model for flat terrains with unwinded conditions valid only to within a factor of 2–5, to superimpose the Saltzman measurement technique for the FRM in the Chattanooga study. Yet Chattanooga is an area of hills and valleys with a single primary NO_2 source (TNT production by the Volunteer Army Ammunition Plant) and is apparently meteorologically stable for only 1 or 2 hours per day for 50% of the days of the year. Since the Army and Public Health Service Saltzman monitors closest to the Chattanooga study FRM monitors were at least 0.04 miles away, attempts to equate Saltzman NO_2 values equal to the FRM NO_2 values observed in the Chattanooga study must fail. This position is fully supported by EPA in its earlier NO_x Criteria where it was observed that:

"[T]he exact location of the sampling site within each city or general area plays a dominent role in determining the concentrations measured. This is illustrated by an examination of those locations . . . that have more than one station in operation. The levels reported in 1969 by two Denver and two Chicago stations show that within any one city the NO_2 yearly averages can differ by factors of 2 to 3, depending on the site." [12]

Health effects data

In considering whether the annual ambient NO_2 standard of 100 ug/m^3 should be about halved to reflect the error in the measurement technique, one should consider all available health data. EPA has not done this to date in its public considerations of the NO_2 ambient standard and the NO_x motor vehicle standard. Perhaps the most glaring example is the omission of the Japanese NO_2 health studies and standard. As indicated in Japan's Air Quality Criteria document for oxides of nitrogen, Japan has established that a 24 hour standard of 0.02 ppm NO_2 is necessary to protect the public health.[13] This standard is several times more stringent than the annual 100 ug/m^3 (0.05 ppm) NO_2 standard which EPA has supported thus far.

The primary scientific basis for the Japanese standard is the "Six Localities Study" in which 2,500 housewives monitored for bronchitis symptoms in six Japanese localities in 1970–71 showed statistically significant increases in symptoms at average NO_2 levels above 0.04 ppm. Another Japanese study is presently monitoring Tokyo school children for various pulmonary function values as correlated with environmental stresses. Initial reports from this study indicate average NO_2 levels of 0.02–0.03 ppm significantly affect the pulmonary functions of the children.

Recent studies by P. M. Sprey of Enviro Control show a strong statistical association between annual mean NO_2 levels down to the lowest NO_2 levels observed (0.03 ppm) and hypertensive heart disease and nephritis. The studies also show a somewhat weaker association of annual NO_2 levels down to 0.03 ppm with respiratory and upper gastrointestinal cancers. An earlier Czech study by Peter and Schmidt showed high methemoglobin (reduced oxygen carrying capacity) levels in city school children exposed to NO_2 levels in the range of 0.01–0.03 ppm. These extra-pulmonary NO_2 effects become all the more significant when compared to animal NO_2 toxicological studies such as those done by Dr. Russell Sherwin that indicate possible mechanisms for these effects. The toxicological studies as well as epidemiological studies are summarized in Attachment A. Attachments B and C present these studies in graph form.

In view of the serious questions about the Chattanooga study revaluation and the additional data on adverse health effects from NO_2 levels far below the present 0.05 ppm annual standard, the ambient NO_2 standard should be reduced by at least one half.

If the ambient NO_2 standard should be reduced by merely one-half to 50 $\mu g/m^3$ (0.0026 ppm) then the statutory 1976 (deferred until 1977) NO_x motor vehicle emission standard of 0.04 grams per vehicle mile is necessary to protect the public health. Since the emission standard does not take effect until the 1977 model year, the NO_x standard should not and need not be changed at this time.

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[12] EPA, NO_x Air Quality at 10–8. A detailed criticism of the EPA position is contained in my July 23, 1973, comments, a copy of which is submitted for the hearing record.

[13] A copy is submitted for the hearing record.

Even accepting the manufacturers' alleged production lead time of two years, a legislative decision on the standard need not be made until August 1974. By then the NAS will have finished their evaluation of the ambient NO_2 standard and the need for the statutory NO_x emission standard. EPA will have also had time to study these issues, evaluate the old and new scientific evidence and make their considered opinion.

In the meantime research and development on NO_x motor vehicle emissions will continue so that the technology will be available to meet the 1976 statutory standards at low cost and good performance if needed to protect the public health. This will permit the following conclusion of EPA in suspending the 1976 NO_x emission standards to happen:

"[T]he technology to achieve '76 statutory emission standards without sacrificing economy of operation, performance and driveability will probably be available in the short term provided research and development continues."

The recent success of Dr. William Balgord of the New York State Department of Environmental Conservation, in meeting the 1975–76 standards for 25,000 miles with a dual catalyst 1972 American Matador that had substantially better fuel economy than other 1972 American Matadors in the New York State fleet is but one example of this developing technology.[14] Take away the 1976 0.4 g/vm NO_x standard and you will take away the incentive to develop cost-effective technology. Even if the 0.4 g/vm emission standard is reinstated when a more stringent ambient NO_2 standard is set, the time lost and the harm to the motor vehicle research and development effort will be irreparable.

Industry proposals

The auto industry and the oil industry have asked that the statutory standards be suspended in order to permit a shift to more efficient alternatives to the traditional internal combustion engine. The major problem with this proposal is that the public will pay for any suspension in terms of health and welfare damages or increased transportation controls. The manufacturers condition any shift to alternative technologies upon meeting their own design, performance and production goals based on their own evaluation of their own data. These condition make any shift to alternatives unenforceable when the manufacturers' goals of 1977–1980 arrive.

If Congress wants to shift to alternative technologies as quickly as possible, then it needs to strengthen, not weaken, Title II of the Clean Air Act. First the useful life of the motor vehicle and its emission control systems should be extended to 100,000 miles from the present 50,000 miles. This gives a clear advantage to alternatives which continue to meet the emission standards throughout their useful life. Second, the recall and warranty provisions of the Clean Air Act should be tightened to put those manufacturers who choose to make less emission durable vehicles at an economic disadvantage. Failure of certain parts such as valves within the useful life of the vehicle should be considered per se violations of the warranty.

These changes would put more efficient, low-polluting alternatives in a better competitive position within the market place. Already consumers are shifting to smaller cars with better gas mileage for economic reasons. The domestic manufacturers have responded by producing more small cars and less large cars to meet this changed demand. By increasing the competitive position of more efficient, less polluting alternatives, similar market responses will occur. At the same time, vehicles will be produced with sufficiently low emissions to meet the standards of the Clean Air Act necessary to protect the public health and welfare.

[14] On October 25, 1973, the Matador met the 1975–76 standards with the following emission results on the Federal Test Procedure: CO—1.77 g/vm; HC—0.23 g/vm; NO_x—0.28 g/vm. Unmodified 1972 Matadors in the New York State fleet got 13 mpg while the dual catalyst Matador got 16 mpg on the same driving schedule.

Attachment A—Health Effects' Deficiencies in the Current Standard

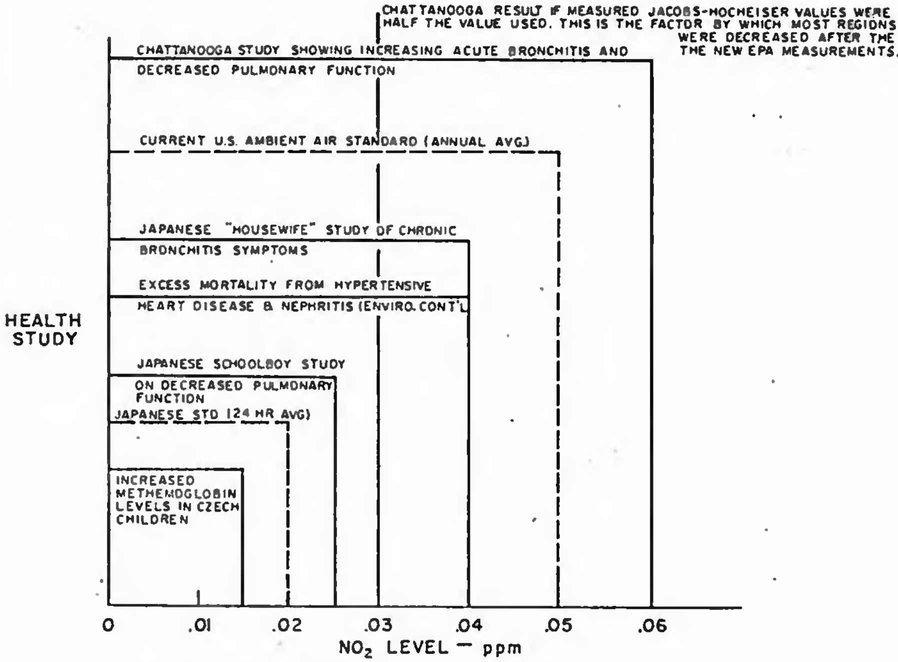
Utilized by EPA	*Available Information Not Utilized by EPA*
PULMONARY EPIDEMIOLOGY	
Only the Chattanooga study indicating excess bronchitis and pulmonary function decrease in school children. Effects said to be at *.06–.1 ppm* (1969). Standard set in 1971 based on this study.	2500 Housewives monitored for bronchitis symptoms in 6 Japanese cities for three months in 1970–1971 showed increase in symptoms at levels of No_2 above *.04 ppm* (average value). Six localities study.
	Another Japanese study is presently monitoring school children for various pulmonary function values as correlated with environmental stresses. The preliminary stages indicate that average levels of *.02–.03 ppm* NO_x for 3–6 months significantly affect the pulmonary functions of the children.
	J. Kagawa & T. Toyama, "Photochemical Air Pollution and Its Effects on Respiratory Function of Tokyo Elementary School Children," Keio University, Tokyo, Japan.
PULMONARY TOXICOLOGICAL STUDIES	
Reduced resistance to bacterial infection at *0.5 ppm.*	Changes in lung wash protein levels at *.4 ppm* for one week in guinea pigs. This is indicative of damaged lung tissue.
Thomas, H. V., P. K. Mueller, and G. Wright. Response of Rat Lung Mast Cells to Nitrogen Dioxide Inhalation. J. Air Pollut. Contr. Ass., 17: 33–35, 1967.	Sherwin, R. P., and D. A. Carlson. Protein Content of Lung Lavage Fluid of Guinea Pigs Exposed to 0.4 ppm Nitrogen Dioxide. Arch. Environ. Health, 27:90–93, (1973).
Blair, W. H., M. C. Henry, and R. Ehrlich. Chronic Toxicity of Nitrogen Dioxide: II. Effects on Histopathology of Lung Tissue. Arch. Environ. Health, 18: 186–192, (1969).	
Ehrlich, R. and M. C. Henry. Chronic Toxicity of Nitrogen Dioxide: I. Effects on Resistance to Bacterial Pneumonia. Arch. Environ. Health, 17: 860–865, 1968.	
Structural changes in lung collagen at *.25 ppm* (may aid in explanation of emphysemic changes) for 4 hours/day for 6 days were noted in rabbits.	
Buell, G. C., Y. Tokiwa, and P. K. Mueller. Lung Collagen and Elastin Denaturation *In vivo* Following Inhalation of Nitrogen Dioxide. California State Dept. of Public Health. (Presented at the Annual Air Pollution Control Association Meeting.) San Francisco. Paper No. 66–7, June 1966.	

ATTACHMENT A—HEALTH EFFECTS' DEFICIENCIES IN THE CURRENT STANDARD—Continued

Utilized by EPA	*Available Information Not Utilized by EPA*
EXTRAPULMONARY EPIDEMIOLOGY	
None.	Statistical mortality data indicating excess deaths from nephritis and hypertensive heart disease. Correlated with NO_2 levels as low as *.03–.04 ppm.*
	Sprey, P. M., K. Allison, and J. Morton, Enviro Control, Inc. A Study of Photochemical Pollutants and Their Health Effects. To be published.
	Sprey, P. Health Effects of Air Pollutants and Their Interrelationships. Contract No. 68–01–0471. Submitted to the Environmental Protection Agency, Washington, D.C. September, 1973.
	Czech study demonstrating very high methemoglobin (reduced oxygen carrrying capacity) levels in school children living in a city with high NO_2 and low SO_2 levels. This compares to low methemoglobin values obtained for children living in a non-polluted city. The high NO_2 city levels are in the range of *0.01–0.03 ppm.*
	Petr, B. and P. Schmidt.[1] The Influence of an Atmosphere Contaminated with Sulfur Dioxide and Nitrous Gases on the Health of Children. Z. Gesamte Hyg. Grenzgeb. 13: 34–48, 1967.
EXTRAPULMONARY TOXICOLOGY	
Tissue changes in lungs, heart, liver, and kidneys of monkeys at *15–50 ppm* NO_2 for 2 hours.	Increased red blood cell enzymes after exposure of guinea pigs to *.36 ppm* for 6 days. In dicates cellular damage and reduced oxygen carrying capacity.
Henry, M. C., R. Ehrlich, and W. H. Blair. Effects of Nitrogen Dioxide on Resistance of Squirrel Monkeys to Klebsiella pneumoniae Infection. Arch. Environ. Health, 18: 580–587, 1969.	Mensch, J., B. J. Dyce, B. J. Haverback, and R. P. Sherwin. Diphosphyoglycerate Content of Red Blood Cells, Arch. Environ. Health, 27: 94–95, 1973.
Approximate doubling of red cell number with lesser increases in hematocrit and hemoglobin in rats exposed to *2.0 ppm* NO_2 continuously for three weeks.	Two fold increase in nephritis of aged rats breathing Los Angeles ambient air compared to filtered air.
Freeman, G., et al. The Subacute Nitrogen Dioxide-Induced Lesion of the Rat Lung. Arch. Environ. Health, 18: 609–612, 1969.	Gardner, M. B., C. G. Lossli, B. Hanes, W. Blackmore, and D. Teebken. Histopathologic Findings in Rats Exposed to Ambient and Filtered Air. Arch. Environ. Health, 19: 637–647, 1969.
	Increased urine protein in guinea pigs (indicating renal problems) after exposure to *0.4 ppm* NO_2 for 4 hours/day for one week.
	R. P. Sherwin, University of Southern California, to be published.

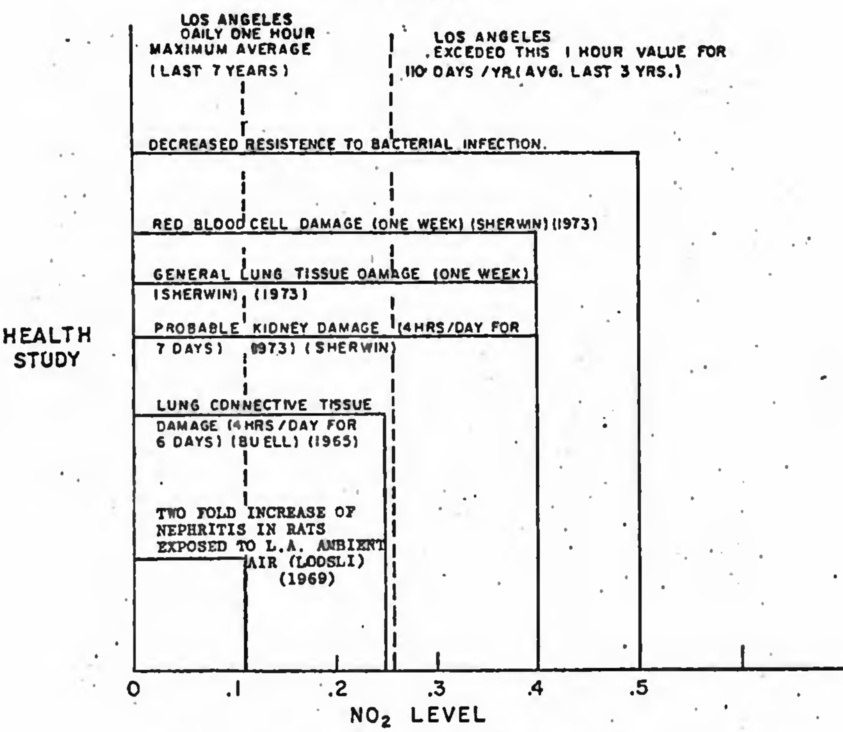
[1] The Petr et al. study is referenced in the Air Quality Criteria for Nitrogen Oxides but is not utilized in conclusary chapter 11 which determines the bounds of the NO_2 health effects.

Attachment B



LONG TERM EPIDEMIOLOGICAL EFFECTS OF NO_2

Attachment C



SHORT TERM TOXICOLOGICAL EFFECTS OF NO_2

STATEMENT OF DAVID G. HAWKINS, OF THE NATURAL RESOURCES DEFENSE COUNCIL, BEFORE THE SENATE COMMITTEE ON PUBLIC WORKS—NOVEMBER 6, 1973

On behalf of the Natural Resources Defense Council I wish to thank the committee for its invitation to testify before it this morning. The questions to be resolved by this committee are simply put even though their answers involve complex considerations. Should Congress change the statutory hydrocarbon and carbon monoxide standards applicable to the 1976 model year? Should Congress change the statutory nitrogen dioxide standard applicable to the 1977 model year? We submit that Congress should make no changes in these standards.

I. HC AND CO STANDARDS

Regarding the hydrocarbon and carbon monoxide standards the first thing the committee should note is that none of the three major auto makers in their testimony yesterday asserted that the HC and CO standards could not be met by model year 1976. Each manufacturer expressed a differing degree of uncertainty about meeting the "1973 interim standards" treated as a unit. However, any difficulty in meeting this set of standards seems to be associated with meeting the NO_x standard of 2.0 grams per mile. It does not appear to be seriously contested that at least the statutory HC and CO standards can be met in model year 1976.

Ford and Chrysler offer several reasons why they believe these standards should not be met in the next few years. The only common objections by Ford and Chrysler are first, that these standards are not necessary to protect health and second, that there is concern about increased sulphate emissions from catalyst equipped cars. All three companies embraced Dr. Arthur Stern's recently published conclusions that all present auto emissions standards are roughly three times more stringent than necessary to protect health. As Senator Muskie pointed out Dr. Stern's calculations were based on presently unprovable assumptions different from EPA's. For example, lower growth rates in future auto emissions and no emission control system deterioration in use were assumed by Dr. Stern. Those who would have us forego the use of available technology based on predictions that it will not be needed in the future bear a heavy burden of proof that their predictions are accurate. Neither Dr. Stern nor the industry has even approached carrying that burden.

Dr. Stern's most significant assumptions were that EPA's underlying ambient air quality standards for HC and CO are wrong. Contrary to the assertion by Mr. Misch of Ford, Dr. Stern did *not* calculate what the auto emissions standards should be to meet EPA's present ambient air quality standards. Dr. Stern assumed much higher ambient standards in his exercise. The three major companies took great pains to stress that they had never criticized the ambient standards necessary to protect health. Yet they rely on someone else's study which *does* reject the ambient standards. Either the companies don't read the reports they embrace or they have been less than forthright with this committee. As for Dr. Stern, his conclusions that the ambient standards could be higher are not supported by the conclusions of the recent NAS conference on health effects of air pollutants, which found "no compelling basis for suggestions to either raise or lower the currently mandated primary air quality standards at this time." In short, the companies' contention that the present emission standards are unnecessary to protect health is not supported. Moreover, as Senator Domenici observed yesterday, given our knowledge of the large contribution of autos to our present pollution levels, the burden should not be on the Congress and the public to establish the precise amount of emission reduction required from autos before imposing some controls.

The problem of sulphate formation in catalyst equipped vehicles is a serious issue which requires prompt resolution. However, we do not think the proper resolution of this issue is to stop plans for the use of catalysts as Ford and Chrysler imply. Existing data on the scope and intensity of the problem are scarce. Measurement techniques are of uncertain comparability. Non-catalyst equipped cars may also emit significant levels of hazardous sulfur compounds. Investigations required to resolve this question must include running more tests using validated measuring techniques. Roadside ambient concentrations of sulphates should be measured now. The auto companies must take a substantial role in these inquiries. This is not EPA's problem as they would have us infer. The industry chose the catalyst. The industry failed to analyze catalyst exhaust gases for sulphur compounds in the early stages of catalyst research and development even though they contended in EPA suspension hearings that extensive periods of laboratory testing of catalysts were responsible for the slow pace of catalyst testing on cars. They now have the gall to attempt to reap the fruits of their own negligence by using it as an excuse for continued inaction. This committee should insist that the manufacturers and EPA rapidly complete research to determine the magnitude of the sulphate problem in catalyst and non-catalyst equipped cars. Avoidance of the problem through removal of sulphur from gasoline and fuel additions is technologically feasible and would appear desirable. Preparations to accomplish this should be undertaken now.

Thus, the principal reasons put forth by Ford and Chrysler to freeze the HC and CO standards do not withstand analysis. General Motors does not make a serious effort to present any reasons why the statutory standards should not be met in 1976. In fact GM's testimony provides compelling reasons why the freeze at 1974 standards would be against the public interest. GM testified that it is able and prepared to install catalysts on a wide range of its 1975 model year vehicles and that a salesweighted *improvement* in fuel economy of 13% over current vehicles will be achieved for the fleet as a whole. However, GM has testified that if the 1974 standards are frozen, competitive pressures will force it to forego catalysts. Thus if Congress grants Ford and Chrysler's request for a freeze of the standards, it will be legislating the introduction of over 5 million GM vehicles next year with a 13% poorer fuel economy than is achievable with available technology. Given the Nation's present and potential energy shortages this is an absurd proposition.

Several Senators sought assurances that a freeze might produce more intensive exploration of new powerplant concepts. Little comfort can be drawn from the companys' responses. GM is four-square for catalysts in the foreseeable future. Ford testified that the catalyst is "the horse to beat." Chrysler "committed" to converting one-third of its engine production during the 1977 model year to a stratified charge engine, but only if the engine should prove to have "the best possible combination of low emissions, low cost, good reliability and easy maintenance, good performance, and improved fuel economy." Anyone who wouldn't jump to produce such a dream car would have to be very stupid. However, Chrysler gives us no real assurance that it will or can make the dream come true by 1977. The question arises why can't they search for this dream even if the standards are not frozen? Chrysler says it would then have to commit its "full resources to the manufacture and maintenance of catalyst systems." Does the company really expect us to support the idea that the first program it should cut back, if it is required to meet present standards, is its alternative power source research and development? What about company expenditures on styling changes, "improved" air conditioning, flashier upholstery and carpeting, support for racing, and other frills? Chrysler, a company with over $220 million in profits in 1972, will spend less than $27 million on emissions in 1973 according to a recent staff study done for this committee. This committee should respond to the manufacturers' bargaining on the new technology issue by reminding them that the public wants both prompt attainment of the standards and exploration of promising new technology.

A freeze of the standards would have a severe impact on the entire State implementation plan process under the Clean Air Act. The many States with severe automotive pollution problems are relying heavily on the statutory emission standards to reduce their clean-up jobs to manageable proportions. The States and EPA have worked long and hard to develop far-reaching transportation control strategies which assume that the statutory emission standards will be met on time. Already burdened State air pollution control agencies will be demoralized to the point of resignation and rebellion if Congress acts to undercut their plans by weakening the standards. In July of this year EPA announced that even with transportation controls some 14 major metropolitan areas could not meet the ambient air standards necessary to protect health until after 1977. If Congress delays the auto emission standards it will be telling the millions of residents of those cities that they must wait even longer before they can expect air fit to breathe.

II. NO_x STANDARDS

The manufacturers claim they cannot meet the statutory NO_x standard and that EPA doesn't think that the standards is necessary. Regarding the availability of technology, the committee should note first that General Motor's testimony does not rule out the possibility of their meeting the statutory standard in 1977. The company says only that it is "not sure" it can meet the standard.

Mr. Cole remarked in an aside that GM is currently running cars at 0.4 grams/mile NO_x, the statutory standard. Given GM's previous hard-line position against the availability of oxidation catalyst technology only a little over a year ago in the spring 1972 EPA suspension hearings, its reluctance to take a similarly negative stance now on reducing catalysts may be a welcome signal that perhaps the situation regarding NO_x technology is not all that bleak. Confirmation for such optimism is provided by reports that a New York State American Motors car equipped with a Gould catalyst is still meeting the statutory standards for all three pollutants after 25,000 miles. The companies have another year in which to bend their efforts to producing a reliable NO_x control technology. Legislative relief is not needed before January 1975. In short, it is not yet time for this committee to reach any conclusions on the availability of NO_x technology. A premature grant of a delay at this time would remove the incentive for maximum efforts during the next year.

As far as EPA's position on the requisite degree of NO_x control is concerned, it has been very tentative to date. The questions it has raised are based on two assumptions: that present ambient levels in most areas of the country are below the present NO_x ambient standard; and that the present ambient standard is adequate to protect health. The Congress should not be asked to act on the basis of EPA assessment of present air quality until the agency has validated a new reference method for measurement of NO_x levels. The cities which have NO_x problems cannot be determined with certainty until that time. EPA first identified only Los Angeles and Chicago as definite problem areas. Recent tests indicate that Denver, Salt Lake City, Atlanta and New York should be added to the list. If the list continues to grow any decision to weaken the NO_x emission standards might have to be reversed in short order. Moreover, the adequacy of the present NO_x ambient standard is under scrutiny as a result of the identification of NO_x as a possible sulphate precursor as well as on the basis of ongoing toxicological studies. These questions call for delaying any consideration of weakening the NO_x emission standard at least until after the NAS has completed its study next August.

In summary, this committee can best discharge its responsibilities by not acting now to recommend any changes in the statutory auto emissions standards or their dates of application. The costs of retrenchment or delay in these standards are real, while the benefits of such action are not proven.

Any future decision to change or delay these standards should be the product of a careful and lengthy analysis of complex factual issues. We suggest that the present legislation sets forth a mechanism which is more likely to produce a correct decision than the present set of hearings which are hampered by inadequate information and inadequate numbers of personnel to assess the information. Section 202(b)(4) of the act provides for EPA monitoring of the process of compliance with the auto emission standards and calls for a hearing and EPA recommendations to Congress should the agency see a possible need for change in the provisions of the statute. If the issues being presented to this committee are not resolved by next summer in favor of maintaining the present standards and timetable, we proposed that EPA convene a hearing similar to the EPA suspension hearings where the manufacturers and others may address all relevant issues including those covered by section 202(b)(5). EPA would then make a recommendation to Congress and Congress would have both the agency's recommendation and an extensive record underlying it to assist the Congress in making any decisions regarding changes in the law.

Mr. ROGERS. Thank you for your testimony.

I think it would be helpful to the committee if you could try to gather facts for us—perhaps you have in the rest of your statement—showing what would happen if you changed the various parts that you say might offer some fuel economy.

Mr. DITLOW. Yes. I would be happy to do that.

Mr. ROGERS. If you could submit that, it would be helpful.

[The following information was received for the record:]

FUEL PENALTIES CAUSED BY AIR CONDITIONERS AND OTHER ITEMS OF OPTIONAL EQUIPMENT ON MOTOR VEHICLES

Air conditioning a car causes fuel penalties from 9 percent to 20 percent according to the Environmental Protection Agency. Using a mid-range penalty of 12 percent, the air conditioning sales-weighted fuel penalty for the 1972 model year was 8.4 percent since 70 percent of all new cars in 1972 were equipped with factory-installed air conditioning. If we conservatively assume that vehicle air conditioners are in use from one-third to one-half of the year, elimination of air conditioners rather than emission controls would cause a fuel economy gain from 3.1 to 5.4 percent. If an auto air conditioner moratorium were begun for the 1975 model year, the Nation could save from 380 to 656 million gallons of gasoline in the first year (1.0–1.8 million gallons per day); during the 1976 model year between 725 million and 1.2 billion gallons could be saved (2.0–3.4 million gallons/day); for 1977 the savings would reach 1 to 1.8 billion gallons (2.8–4.9 million gallons/day).

Some auto industry executives have suggested that up to 2.7 billion gallons of gasoline could be saved annually by removing emission controls from vehicles-in-use. By comparison removal of air conditioners from vehicles-in-use could save up to 3.9 billion gallons of gasoline annually.

Air conditioning is just one of several equipment changes that can save fuel without endangering health. Items such as power sunroofs, power windows, power seats, automatic transmissions and vinyl roofs are additional candidates. The use of radial tires rather than normal Bias-ply tires can improve fuel economy an additional 3 percent.

CAUSES OF FUEL ECONOMY LOSSES ON AUTOMOBILES

Fuel economy of automobiles is affected by many factors. Gasoline-powered cars in 1974 exhibit fuel economy variations over a range of 4 to 1, i.e., from about 29 mpg to about 7 mpg. The following table identifies the most important design factors that govern fuel economy:

Factor	*Fuel Economy Impact*
Vehicle weight is the most important factor. 1974 vehicles range from 2000 lbs to over 5500 lbs. Vehicle weight has increased by about 20% since 1962.	Fuel economy is directly proportional to weight, i.e., a 5000 lb car takes twice as much fuel per mile as a 2500 car. About half of fuel economy loss since 1962 is due to vehicle weight.
Air conditioning uses fuel both through use, and through added weight.	9%–20% fuel economy loss when operating, depending on temperature and humidity, and on design features.
Automatic transmissions require more fuel, for weight reasons and because of internal losses.	Losses range from 2% to 15%, depending on the type of transmission.
Compression ratio reduction to permit operation on 91 octane gas.	3.5% fuel economy loss.
Emission controls on 1973/74 cars have varying impacts, depending on vehicle weight.	On small cars (compacts and subcompacts) there is a slight gain in fuel economy; on large cars there have been losses ranging up to 18%. Sales-weighted average loss for all cars is about 10%.
Emission controls on 1975 cars, to meet the Federal interim standards, will be largely catalytic and will improve fuel economy.	Estimates of fuel economy gains vary. GM estimates average gain of 13%, up to 18% on large cars, over 1973/74 cars. Ford and Chrysler estimate lesser gains.

Mr. ROGERS. Mr. Satterfield.

Mr. SATTERFIELD. Mr. Chairman, I do not have any questions of Mr. Ditlow except for the last paragraph of his statement that he did not read. I just wanted to know what you mean by "the choice must be made on limiting auto equipment use to save energy, vote to give the public clean air over cold air."

I do not understand what you mean by that.

Mr. DITLOW. We mean clean air from the emission controls versus cold air from the air-conditioners.

Mr. ROGERS. Dr. Carter.

Mr. CARTER. Thank you, Mr. Chairman.

I notice that you are strong on public transportation, and I agree that that certainly would help a great deal. More than likely we made mistakes years ago when we got rid of our buses and streetcars.

Mr. DITLOW. Yes.

Mr. CARTER. I am glad to see that our Nation is going forward in this area.

Now, of course, you are correct in your statement about air-conditioners, the weight of cars, and so on. We all realize that. It is going to be rather difficult for 70 percent of us at least to get used to it.

Now, I notice you would ban power windows. Would you also ban power brakes and power steering?

Mr. DITLOW. If you decrease the weight of the vehicle, then power steering and power brakes are no longer needed because they were put on primarily to offset the increase in vehicle weight.

Mr. CARTER. Well, I think that is true; but do you think they add to safety in most cases? Is there not a safety factor there?

Mr. DITLOW. There is in the larger vehicles, particularly for the fifth percentile person who does not have the strength to operate the controls.

Mr. CARTER. Well, I think that there would be a safety factor, because it is rather difficult to steer.

Mr. DITLOW. I agree that it is in some heavier vehicles, but if you put power steering on a Volkswagen, you would be in worse condition.

Mr. CARTER. Thank you.

Mr. ROGERS. Thank you.

Mr. Preyer.

Mr. PREYER. I have no questions. Thank you very much for a good statement.

Mr. ROGERS. Mr. Hastings.

Mr. HASTINGS. I have no questions either. I just have one correction. You talk about on the second page of your testimony that a decision with the consequences that would be discussed should be subject to more notice than one afternoon of hearings.

Mr. DITLOW. When we first read this, there was only one afternoon scheduled.

Mr. HASTINGS. Also bear in mind we had oversight hearings on the Clean Air Act in September that were rather extensive. So in addition to the 3 rather full days of hearings that we are now having, we also had the benefit of those oversight hearings in September.

Not that I disagree with your statement at all, but I just want to make sure it is correct.

Mr. DITLOW. Yes. And the attachments to my statement were also prepared to be submitted at that time.

Mr. HASTINGS. Thank you very much.

Mr. ROGERS. Mr. Symington.

Mr. SYMINGTON. Thank you, Mr. Chairman.

Of course, we have to consider any decision that we make in the totality of the impact on the economy and the public health. And I take it that the 1975–76 standards were adopted and suggested not in a vacuum of expectation, but in the expectation that a certain number of cars are going to be on the road and that standards would be affected detrimentally.

Now we are told by the Energy Office that they expect a 25-percent or 24-percent reduction in the number of cars that will actually be driven. And if that is the case, it seems to me that that should be factored in to the decision as to the necessity of going forward with standards that are based not on a 24-percent reduction, but perhaps a 50-percent increase given the exponential growth of the car population absent this crisis.

Have you factored that into your studies?

Mr. DITLOW. I have not in the time allowed me, but I suggest you just compare the vehicle mile travel reduction required by EPA in the implementation plans versus the shortfall in gasoline. You will find that in the example of Los Angeles, the gasoline VMT reductions proposed by EPA vastly exceed any of the projected shortfalls of the Energy Office. So that we will indeed still need transportation controls to reduce automobile emissions, even given a shortfall in gasoline.

Mr. SYMINGTON. You are talking about private automobile vehicle miles are expected to increase in spite of a 25-percent reduction in automobile——

Mr. DITLOW. No. What I am saying is that EPA has said in Los Angeles in order to meet the ambient air quality standards by 1977, we need something like an 86-percent reduction in vehicle miles traveled. And if you accept that we will have, say, an estimate of even 50-percent less gasoline or 50-percent less cars on the road because of that less gasoline, it will still be exceeded by the 86-percent required in Los Angeles.

Mr. SYMINGTON. Of course, there is a disparate test and criterion now between Los Angeles and the rest of the country. Are you suggesting that we should have the Nation meet the tests necessary for Los Angeles?

Mr. DITLOW. No. What I am suggesting is there are some 38 regions which require transportation control plans; these are most of the major urban areas in the country. And I am suggesting if you examine those in the time frame given them until 1977, that indeed you will still see that you need reductions in vehicle traffic, despite the gasoline shortage.

Mr. SYMINGTON. All right.

Thank you, Mr. Chairman.

Mr. ROGERS. All right.

Mr. Heinz.

Mr. HEINZ. Mr. Chairman, I thank you. I have no questions for the witness.

Mr. ROGERS. Dr. Roy.

Mr. ROY. No questions Thank you, Mr. Chairman.

Mr. ROGERS. We are very grateful to you for being here. Thank you. If you would let us have that information, that would be helpful.

Mr. DITLOW. Yes.

Mr. ROGERS. This concludes the hearings. I think the committee will want to get together if we can this afternoon. We will touch base with you to see what may be possible, depending on what the full committee does. We will try to notify offices.

Thank you so much. The hearing is concluded.

[The following letters were received for the record:]

ASHLAND OIL, INC.,
Ashland, Ky., December 3, 1973.

HON. PAUL G. ROGERS,
Chairman, Subcommittee on Public Health and Environment of House Committee on Interstate and Foreign Commerce, Washington, D.C.

DEAR CONGRESSMAN ROGERS: Ashland Oil is in agreement with the recent proposals that additional burning oils can he manufactured by minimizing gasoline production. Most catalytic cracking units can operate satisfactorily at 50% of capacity, thereby increasing burning oil production by as much as 15%. Most of this additional production will be heavier than No. 2 fuel oil but certainly could be adapted to be used in industry in a relatively short period of time. If additional fuel oils are manufactured from cat cracker charge, three things must be considered:

(1) In order to maintain general refining economics the fuels produced must he priced on parity with gasoline.

(2) Because of the reduction of high octane blending components from the cat cracker, the lead phase-out program must be deferred until the energy problems are solved.

(3) Snlfur limitations must be relaxed hecause the cat cracker feed is generally higher in sulfur than the No. 2 fuel oil that is produced in most refineries.

The enclosed memorandum goes into more detail covering generally the operation of an oversimplified refinery we think typifies most domestic operations.

Cordially yours,

ROBERT E. YANCEY,
President.

NOVEMBER 23, 1973.

Memorandum.

From: Robert E. Yancey.

Suhject: Maximum refinery heating oil yields at expense of gasoline.

The gasoline shortage is less critical at this time than the shortage of fuel and other heating oils. It has also been projected that the Government could dictate what products are to be made from a refinery within the limits of its capability. Recent questionnaires have been circulated as to how much additional fuel oils can be manufactured hy minimizing the production of gasoline. If we oversimplify a typical domestic refinery, it consists of three basic units—a crude distillation unit including a vacuum unit, a catalytic reforming unit, and a catalytic cracking unit. In the crude distillation process four primary products are produced. These are (1) the overhead product straight run gasoline, which includes cat reforming charge, (2) kerosene and virgin gas oil, which go primarily into diesel fuel, home heating and other industrial uses, (3) catalytic cracking charge stock, and (4) asphalt or residual fuel oil.

About 30% of crude oil is overhead product, about 20% is kerosene and virgin gas oil, about 15% is residual fuel oil and asphalt, and the balance (approximately 35%) is catalytic cracking charge stock. Again, this is an over-simplification since many crudes have a different yield from distillation, but on balance this should be near average for most conventional U.S. refineries. Therefore, the only major source of additional fuels for industry and utilities is the 35% catalytic charge stock and that portion of the 15% bottoms which could be processed into No. 6 fuel oil instead of the normal asphalt. It should be noted that asphalt is generally high in sulfur content and requires about 50% No. 2 fuel oil as diluent to make viscosity spec on No. 6 fuel oil.

Because of the configuration of most refineries, it is not practical to shut down a catalytic cracking unit completely. However, most of these plants could be operated without difficulty at something in the neighborhood of 50% capacity. This, then, would allow an additional 17.5% of the total crude breakdown to be made available for distillates in the range of No. 3, No. 4, No. 5, and residnal fuel oils. These products would not he as desirable as No. 2 fuel oil, but most industry—faced with shutdown—could he eqnipped within a short period of time to handle such fuels.

The poor octane number of the gasoline from this proposed refining operation will be approximately 95 with 3cc tetraethyl lead per gallon. The pool octane required is 94.2, assuming 80% regular at 93 octane and 20% premium at 99 octane.

The main reasons for refineries to operate maximizing cat cracker feed are:

(1) Yields maximum gasoline which, because of market demand and Cost of Living Council regulation, is the highest priced product produced in any volume in the refinery.

(2) The cat cracked gasoline is the highest octane pool component going into finished gasoline blends.

If additional fuels are manufactured from the cat cracker charge stock available, three things must be considered:

(1) The fuels produced must be priced on parity with gasoline.

(2) Because of the reduction in high octane gasoline blending components, the lead phase-out program would of necessity have to be deferred until the energy problems are solved.

(3) Sulfur specifications must be relaxed because catalytic cracker feedstocks are generally higher in sulfur than other distillate fuels.

If we are to maintain the type of business activities that we have all enjoyed over the last several years, we must protect American business preferentially. Even before the embargo, it was apparent that certain restraints on the use of gasoline had to be exercised because of the overall shortage of refining capacity in the United States and, for that matter, the entire world. Certainly to maintain the vitality of American industry, Americans' use of gasoline must diminish.

The automobile industry has been the chief offender in causing the increased use of energy. The Clean Air Act of 1970 has also contributed to the critical shortages we now face. Rather than debate the pros and cons of gasoline as it pertains to emissions, I think a much more serious matter is the lack of fuel to continue the type of industrial development the United States has enjoyed in the past years. The only source of these fuels for the short term is, of course, to increase fuel oil yields at the expense of gasoline. The extent of this possibility has not been fully evaluated, but I'm sure that given the incentive the refiner can increase his total fuel oil production in the form of No. 2, No. 3, No. 4, and No. 6 fuel oils by a minimum of 15%. However, to make a satisfactory quality gasoline the high octane components normally derived from the cat cracker will have to be substituted for by the continued use of tetraethyl lead. Therefore, the lead phase-out program must be delayed until adequate crude oil and refining capacity are available to meet the entire energy needs of the Nation. Also, sulfur regulations must be relaxed in order to maximize all fuel oil production.

NATIONAL PARKING ASSOCIATION,
Washington, D.C., December 4, 1973.

Hon. PAUL G. ROGERS,
Rayburn House Office Building,
House of Representatives, Washington, D.C.

DEAR MR. CHAIRMAN: National Parking Association is the trade association representing the commercial, off-street parking industry in the United States and twelve foreign countries. Our members make up approximately eighty-five per cent of the commercial parking industry. I am writing this letter to express our members' strong opposition to the White House plan to further delay implementation of automobile emission standards.

On September 21 of this year, National Parking Association presented written testimony to your Public Health and Environment Subcommittee advocating a twelve-point program for achieving cleaner, healthier air in our cities, with less harm to the economic base of metropolitan areas than some proposals advanced by the Environmental Protection Agency. One of the points in our program read:

"We encourage the fastest possible development of a pollution-free automobile engine."

We still support this.

Unfortunately, in the Administration's long-delayed crash program to deal with severe energy shortages, it has chosen to "take it easy" on the primary source of pollution and depleted gasoline supplies—the automobile engine.

It is our understanding that the EPA is currently calling for a reduction of up to thirteen per cent in vehicle miles traveled in the Washington, D.C. area alone. This is to reduce the amount of vehicle emissions polluting the air in and around the nation's capital. If, however, the emission standards scheduled for compliance in 1975, are delayed until 1977, the VMT reduction in this area would almost double; a reduction of almost twenty-five per cent. According to the D.C. Motor Vehicles Division, this would eliminate at least 360,000 trips every day.

It seems to many of us in auto-related industries, that allowing the manufacturers a further delay in meeting their standards while imposing more strict traffic and parking regulations on others is treating the symptoms, not the cause.

At best, the White House assumptions on the effect of the catalytic converter on fuel economy are questionable. Even General Motors, the giant of the automobile industry, and not exactly what one would call the strongest environmentalist organization around, has said not only that its catalysts can meet the present standards, but will improve performance *and* fuel economy. You and the committee heard testimony yesterday from EPA Administrator Russell Train that, indeed, the catalytic converter could produce a fuel economy *bonus* of between five and thirteen per cent over 1973–74 levels.

National Parking Association realizes the need for some of EPA's transportation controls and we have no wish to argue for the status quo when we know that the air *must* be cleaned up. We are being hit hard by certain EPA regulations for some of our largest cities and we think we are reacting responsibly and realistically. Our members cannot sit on their hands, however, while the car makers get delay after delay and auto-related industries get pushed closer to the brink of financial disaster. Stock in some of our publicly owned companies has plummeted by as much as eighty per cent under the threat of heavy parking restrictions.

We believe the delay in meeting emission standards could signal great danger to the public health if the White House amendment delay idea is enacted. As you and the committee members know, the "primary" air quality standards are set just high enough to protect health and life itself. These primary standards could be ominously threatened in many areas if the manufacturers are not required to install catalysts and other pollution devices *at least* on the presently required schedule.

Frankly, Congressman, it comes down to this: The more delays allowed in meeting emission standards, the harder it's going to be on millions of drivers who will be hit by possibly *doubled* transportation restrictions, and the tougher it's going to be for many downtown businesses to survive. This is to say nothing of the detrimental effects further delay would have on the public health.

National Parking Association has had occasion to disagree with Mr. Train over some EPA controls in the past. In this instance, however, we fully concur with Mr. Train's recommendation that *no changes be made* in the automotive emission standards at this time.

I thank you for your attention, urge your strong consideration of these views, and ask that this statement be placed in the record of the subcommittee hearings.

Sincerely,

NORENE DANN MARTIN,
Executive Vice President.

[Whereupon, at 10:10 a.m., the hearing was adjourned.]

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